

Continuations

High-Level Control Operators

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Software Architecture Group

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<http://www.hpi.uni-potsdam.de/swa/>

11.01.2012

A Program

```
makeOne
```

```
| one |
```

```
one := 1.
```

```
^ one
```

```
makeTwo
```

```
| one |
```

```
one := 1.
```

```
^ self makeOne + one
```

```
makeThree
```

```
| one |
```

```
one := 1.
```

```
^ self makeTwo + one
```

A Program

13 <76> pushCon stant: 1	14 <68> popIntoT emp: 0	15 <10> pushTem p: 0	16 <7C> returnTop
---	--	---	---

makeOne

17 <76> pushCon stant: 1	18 <68> popIntoT emp: 0	19 <70> self	20 <D0> send: makeOne	21 <10> pushTem p: 0	22 <B0> send: +	23 <7C> returnTop
---	--	--	--	---	---	---

makeTwo

17 <76> pushCon stant: 1	18 <68> popIntoT emp: 0	19 <70> self	20 <D0> send: makeTwo	21 <10> pushTem p: 0	22 <B0> send: +	23 <7C> returnTop
---	--	--	--	---	---	---

makeThree

A Program

makeThree

17 <76> pushCon stant: 1	18 <68> popIntoT emp: 0	19 <70> self	20 <D0> send: makeTwo	21 <10> pushTem p: 0	22 <B0> send: +	23 <7C> returnTop
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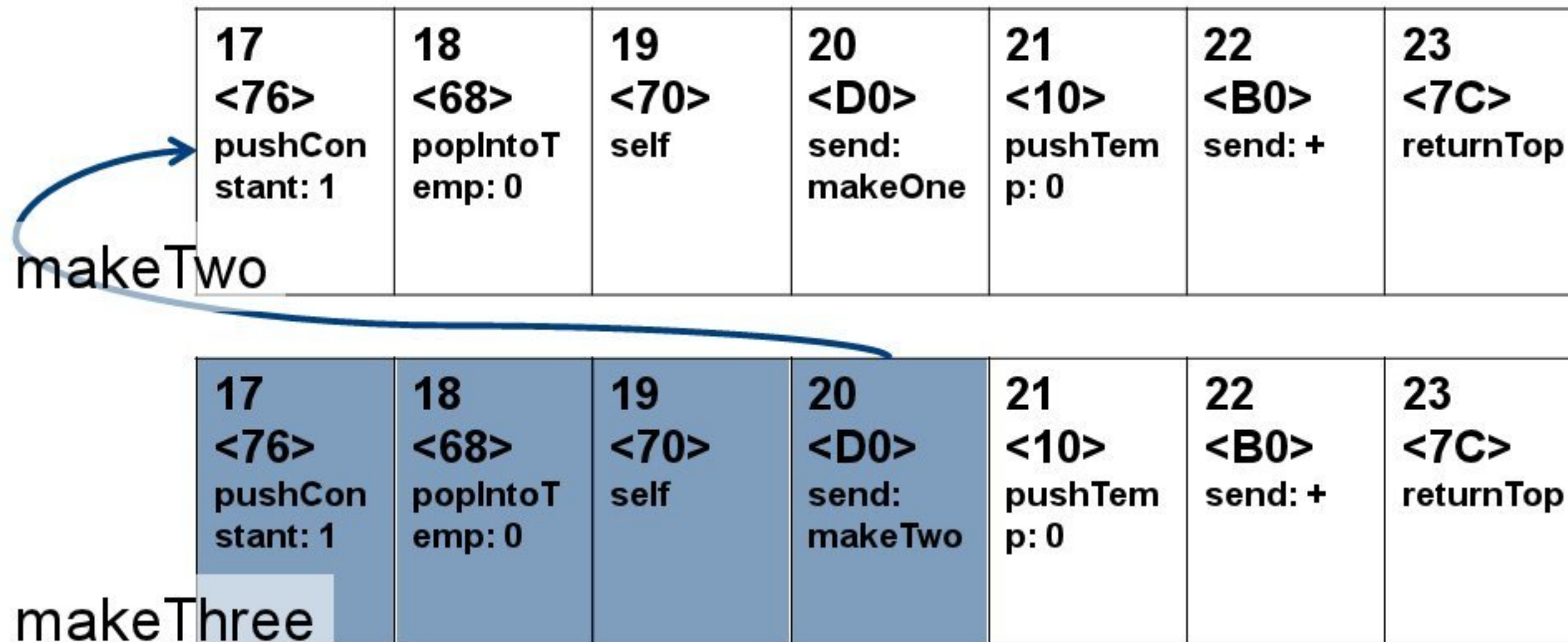
makeThree

A Program

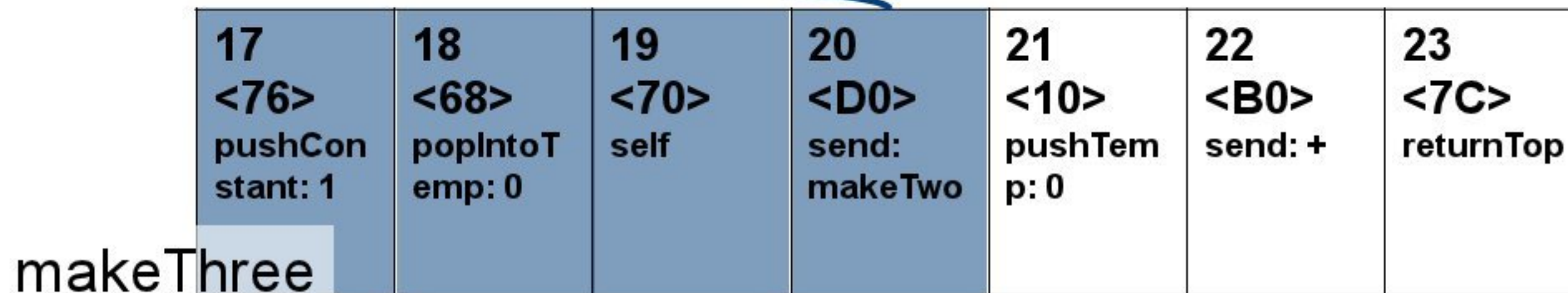
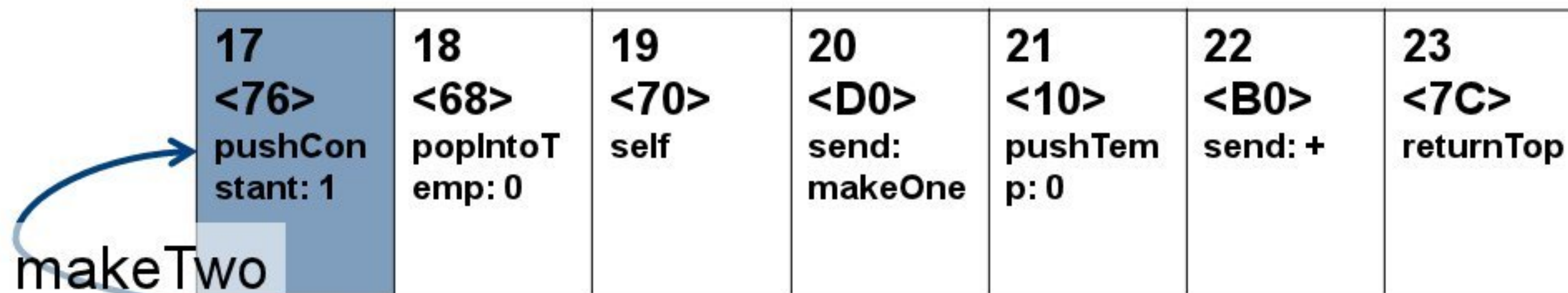
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makeThree

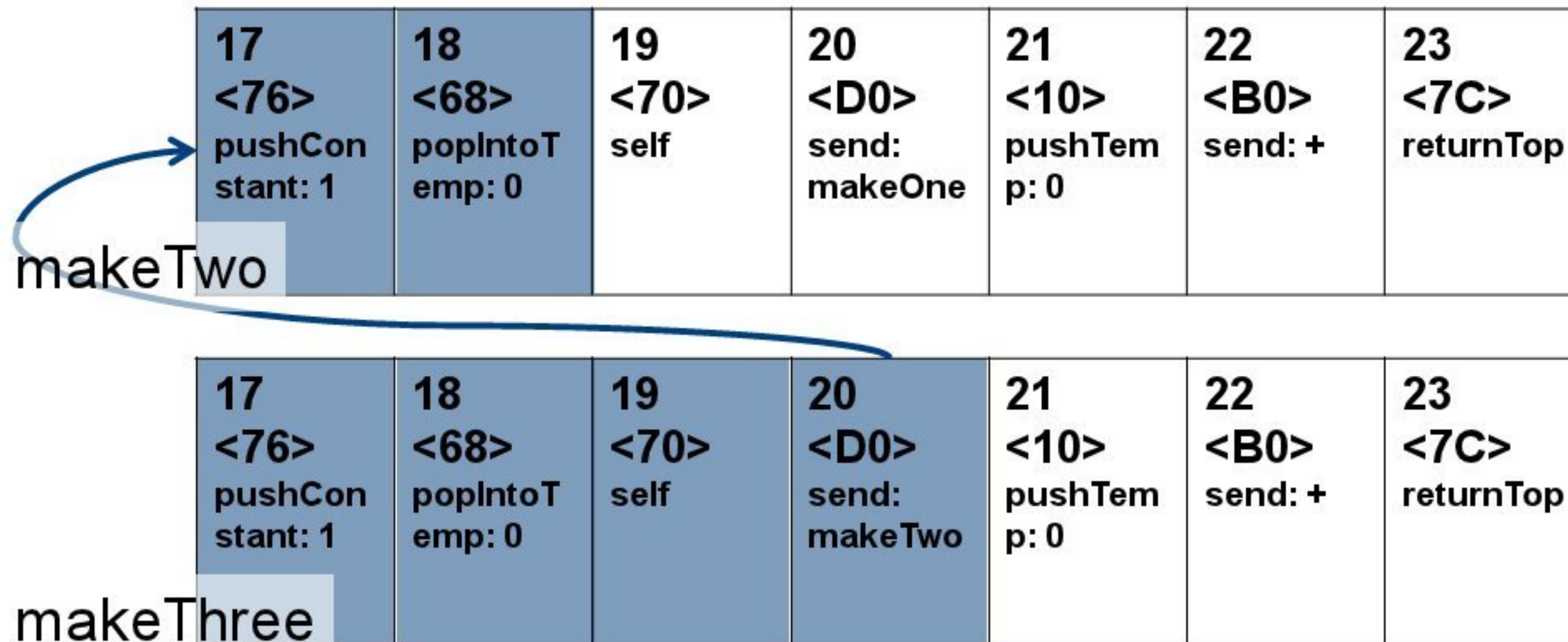
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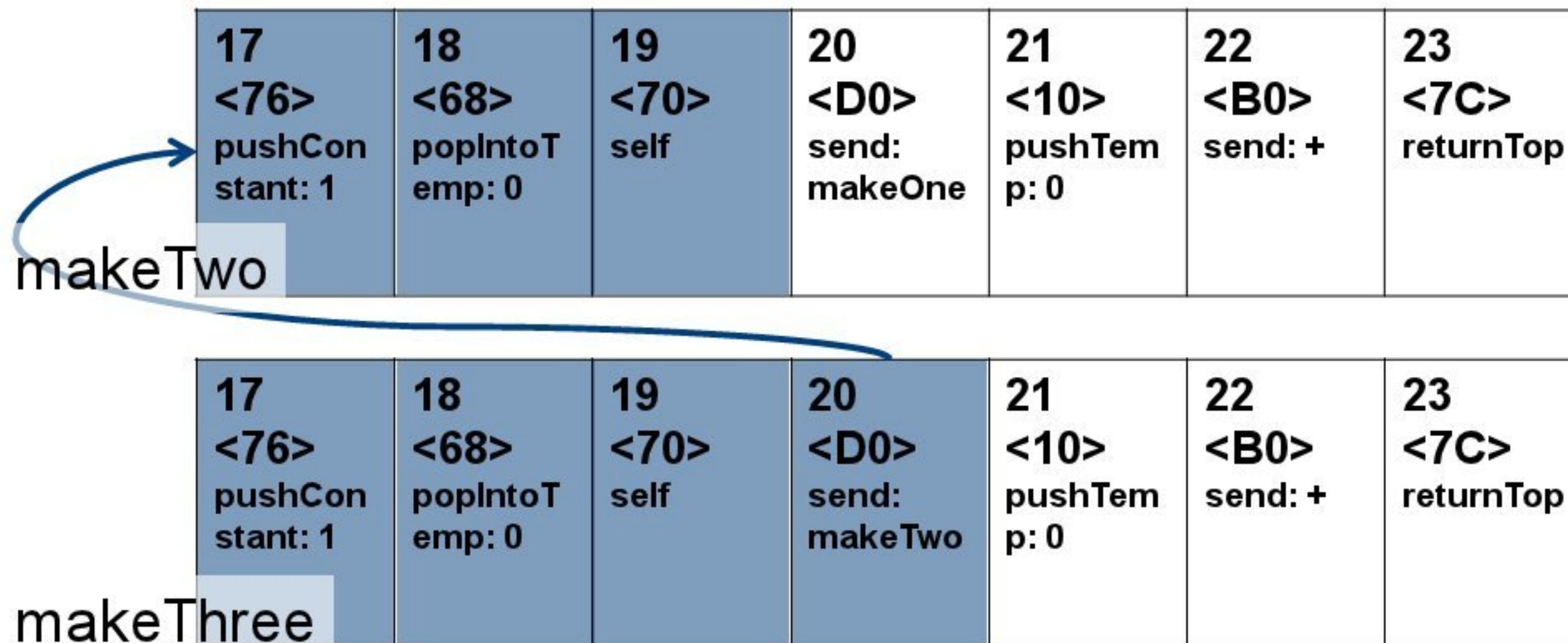
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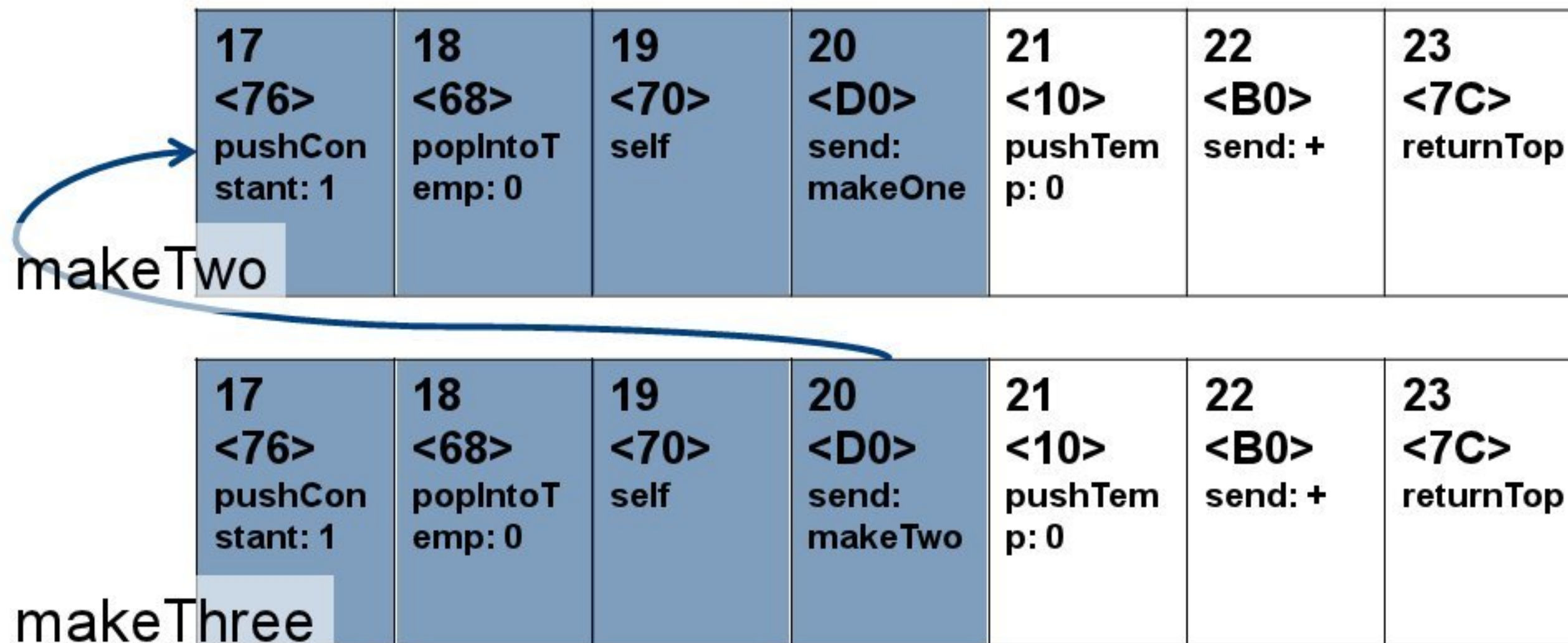
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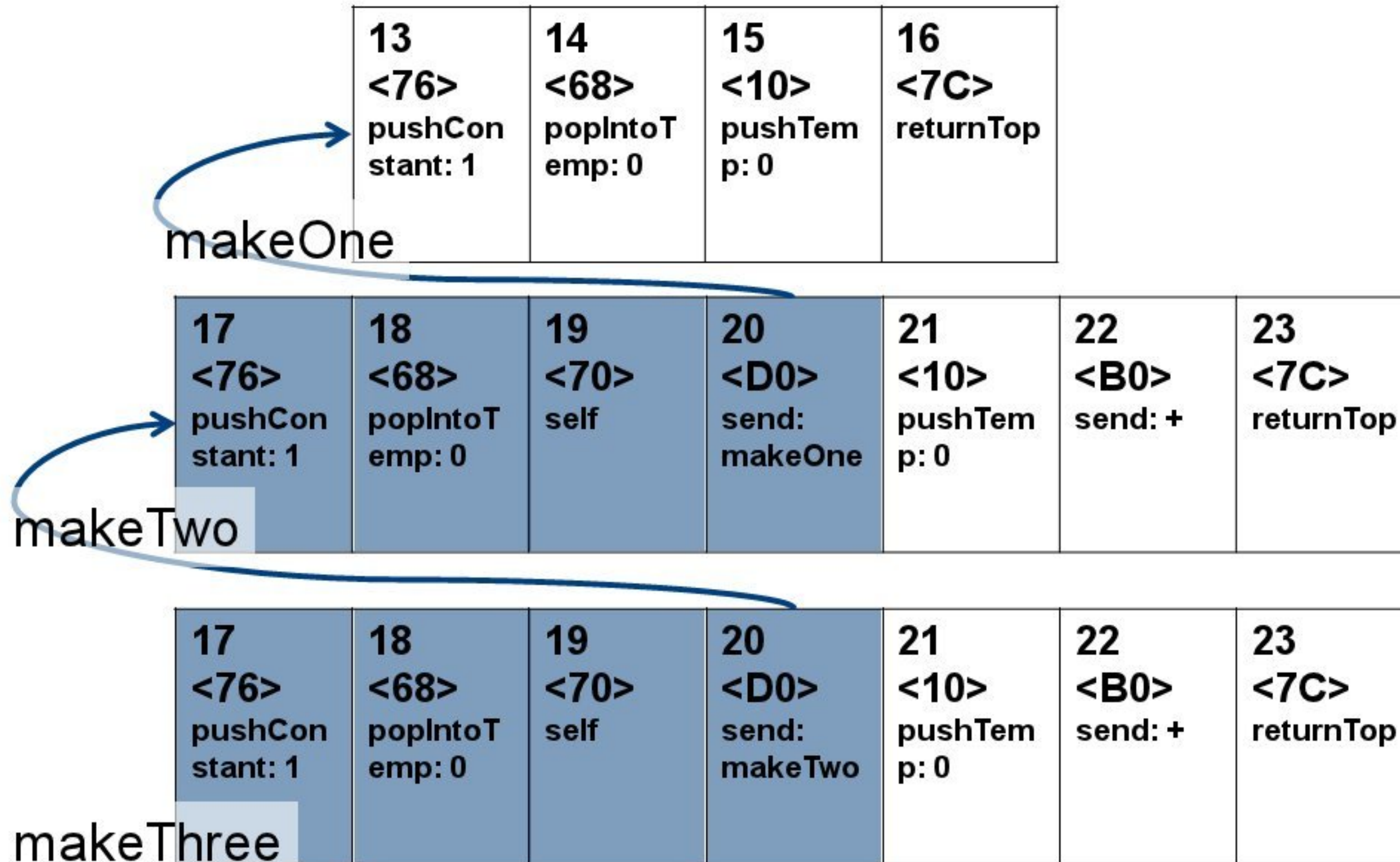
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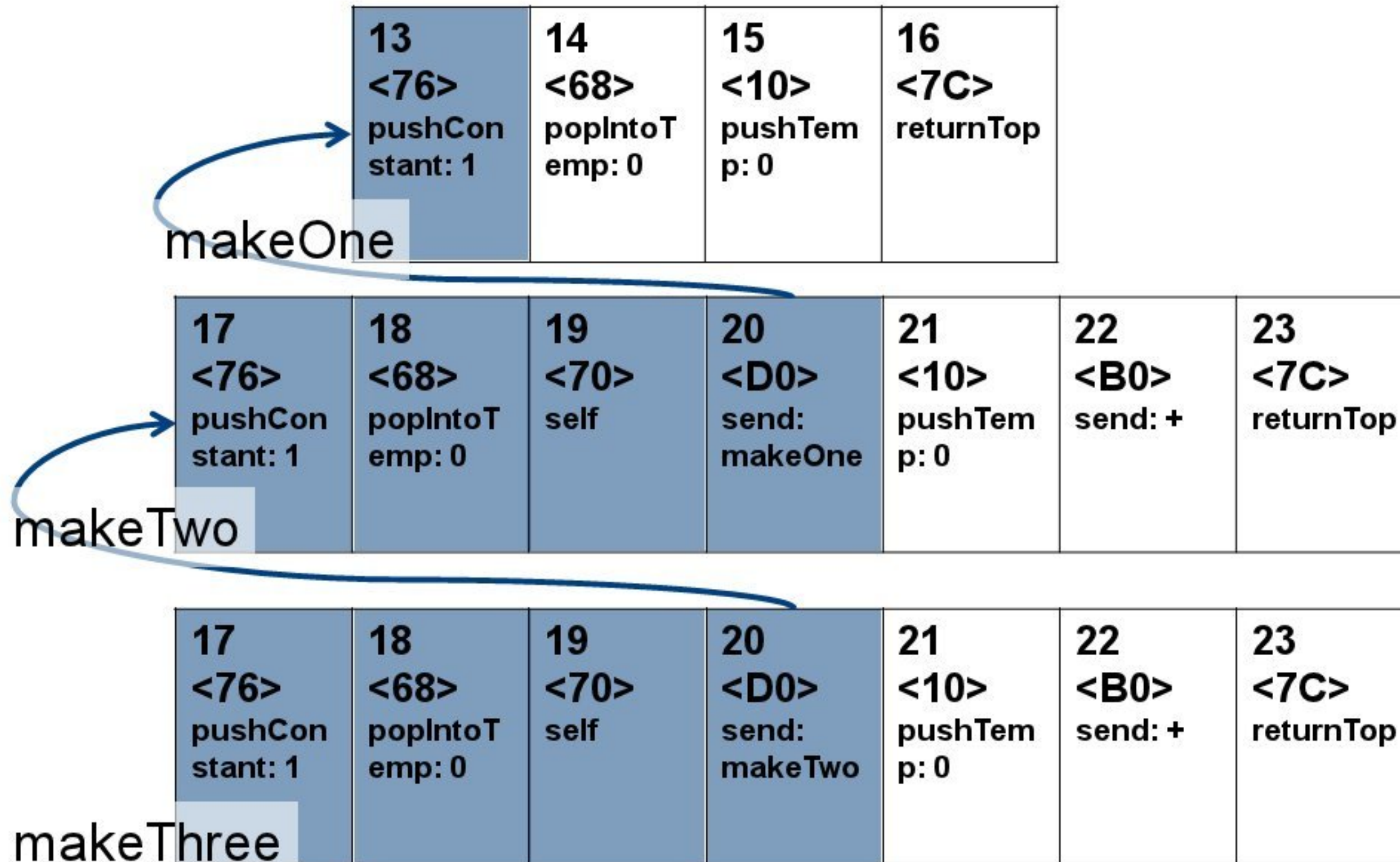
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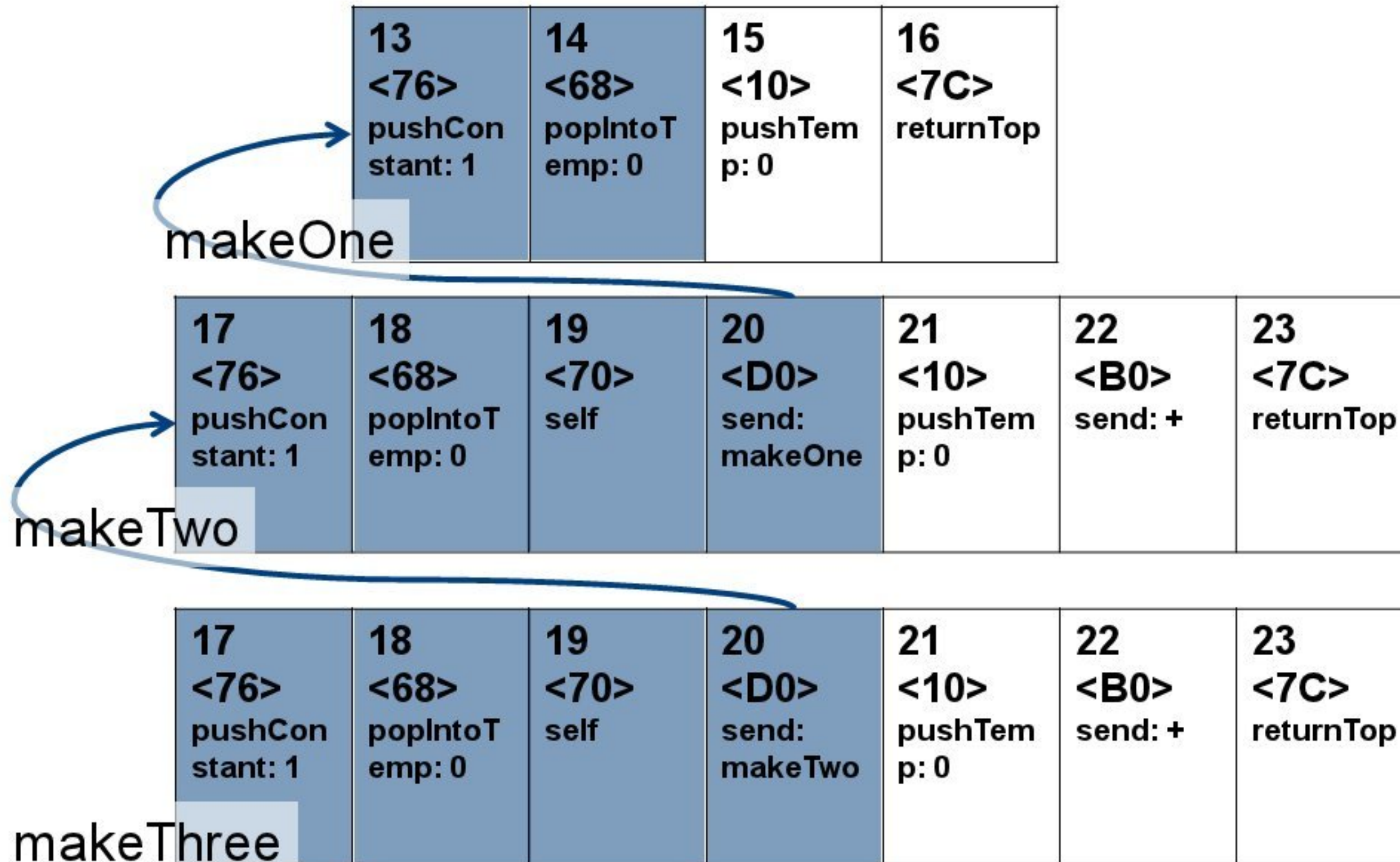
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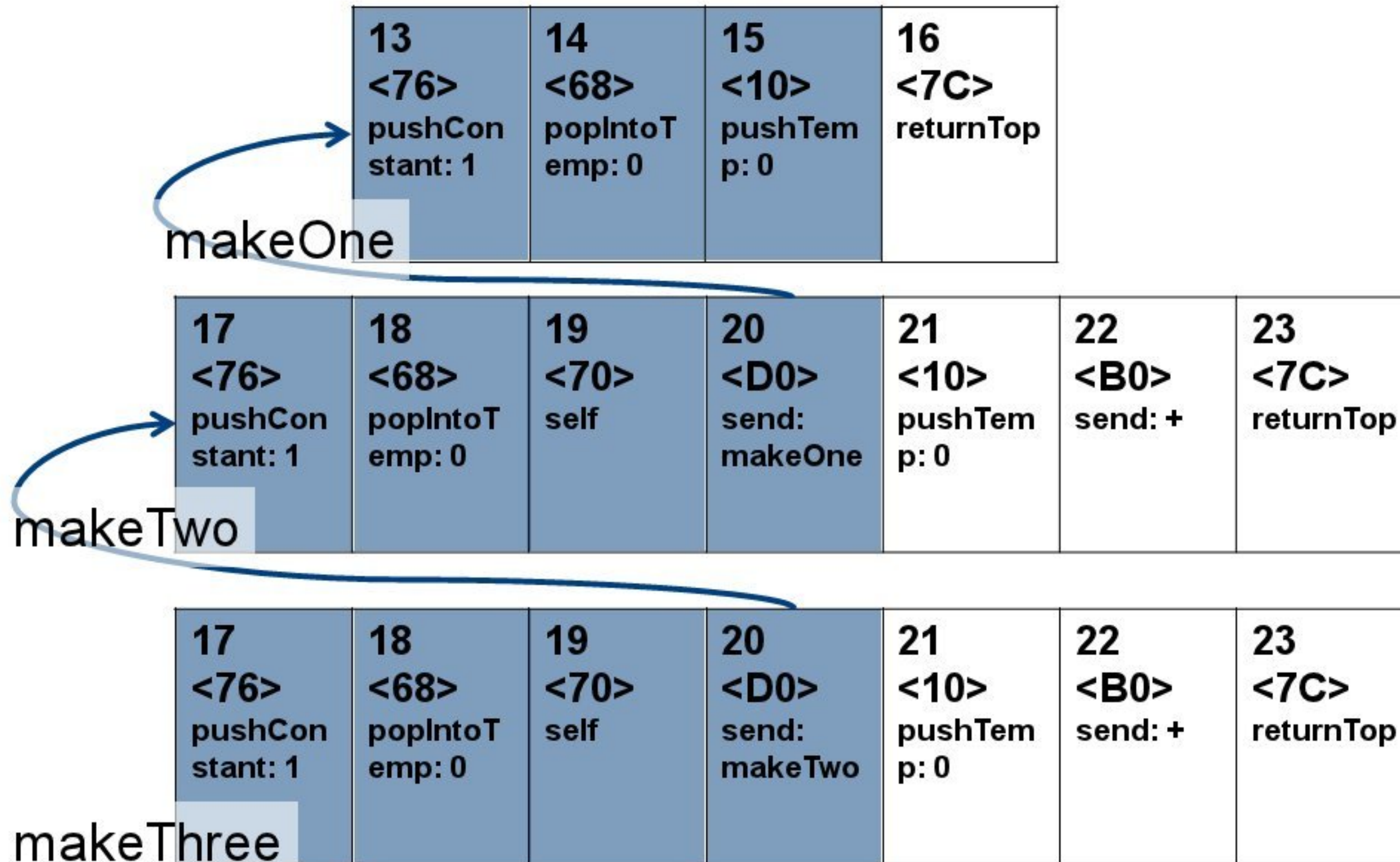
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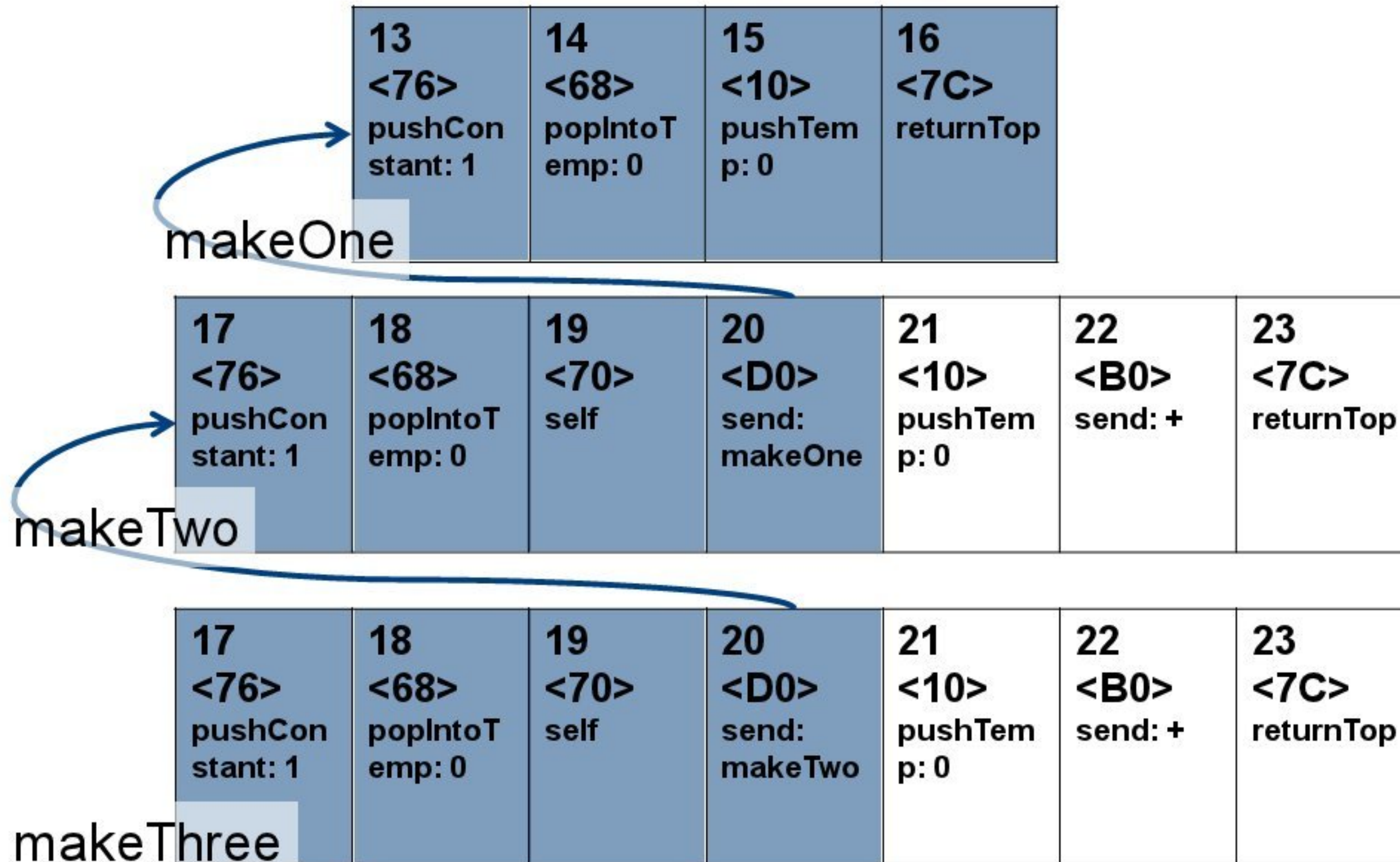
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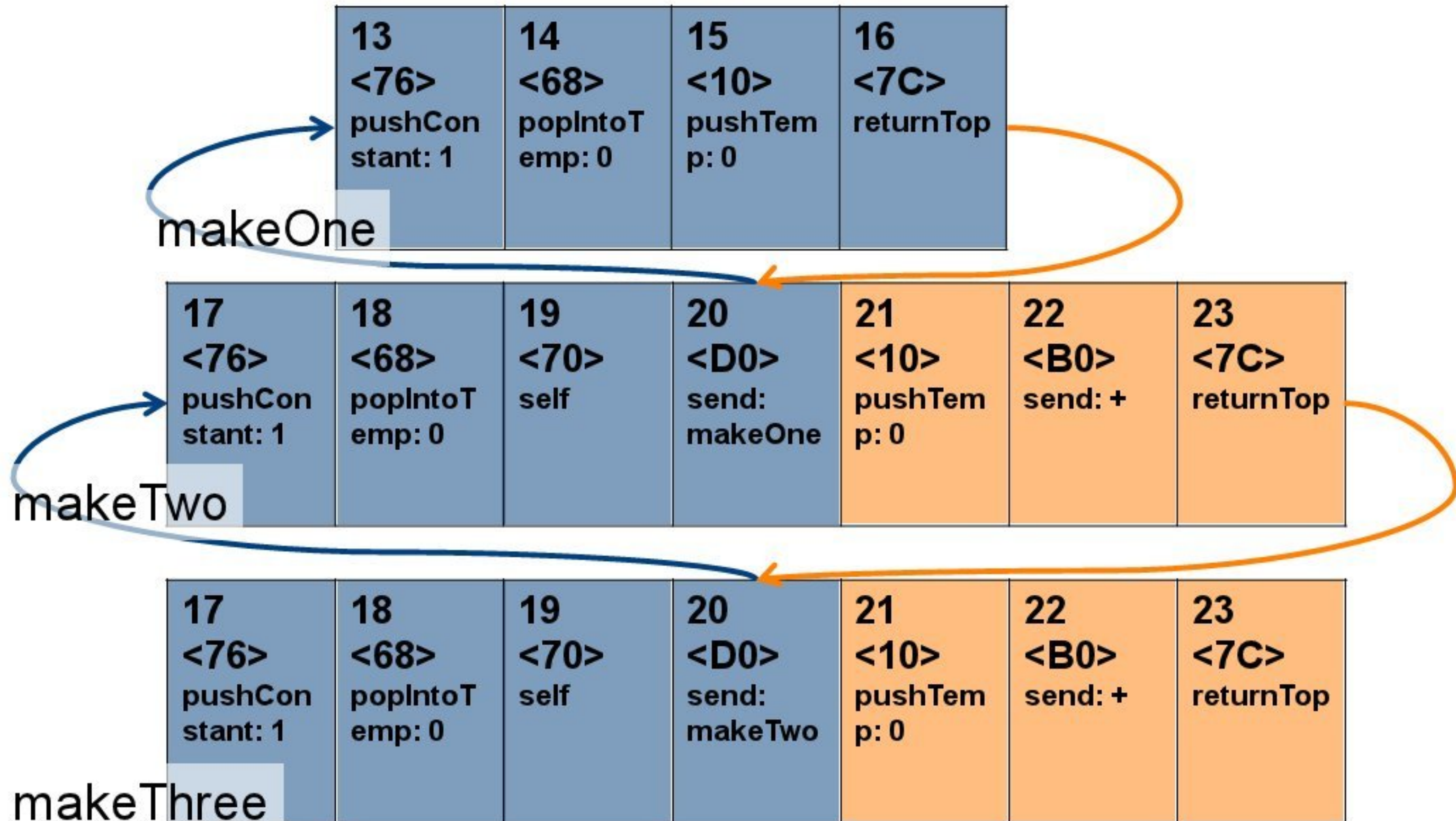
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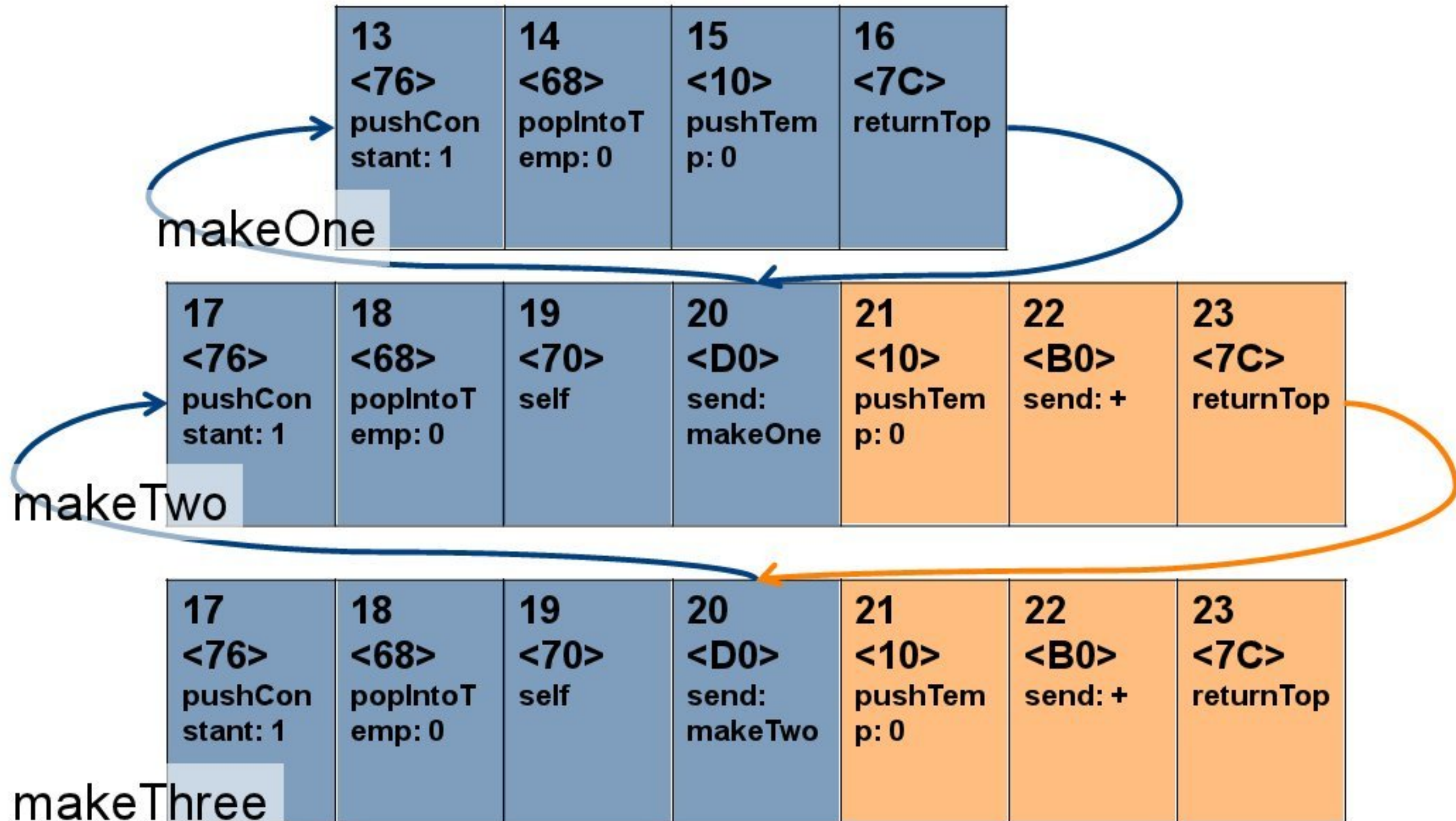
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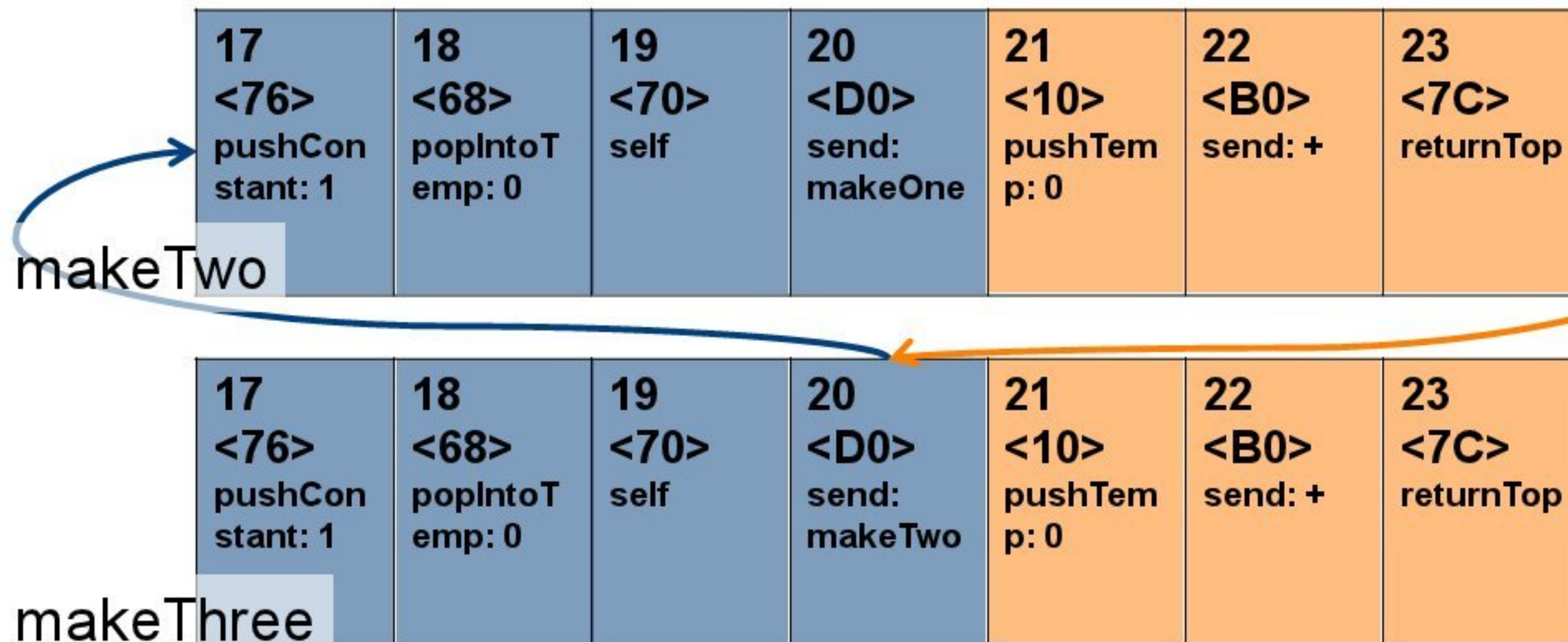
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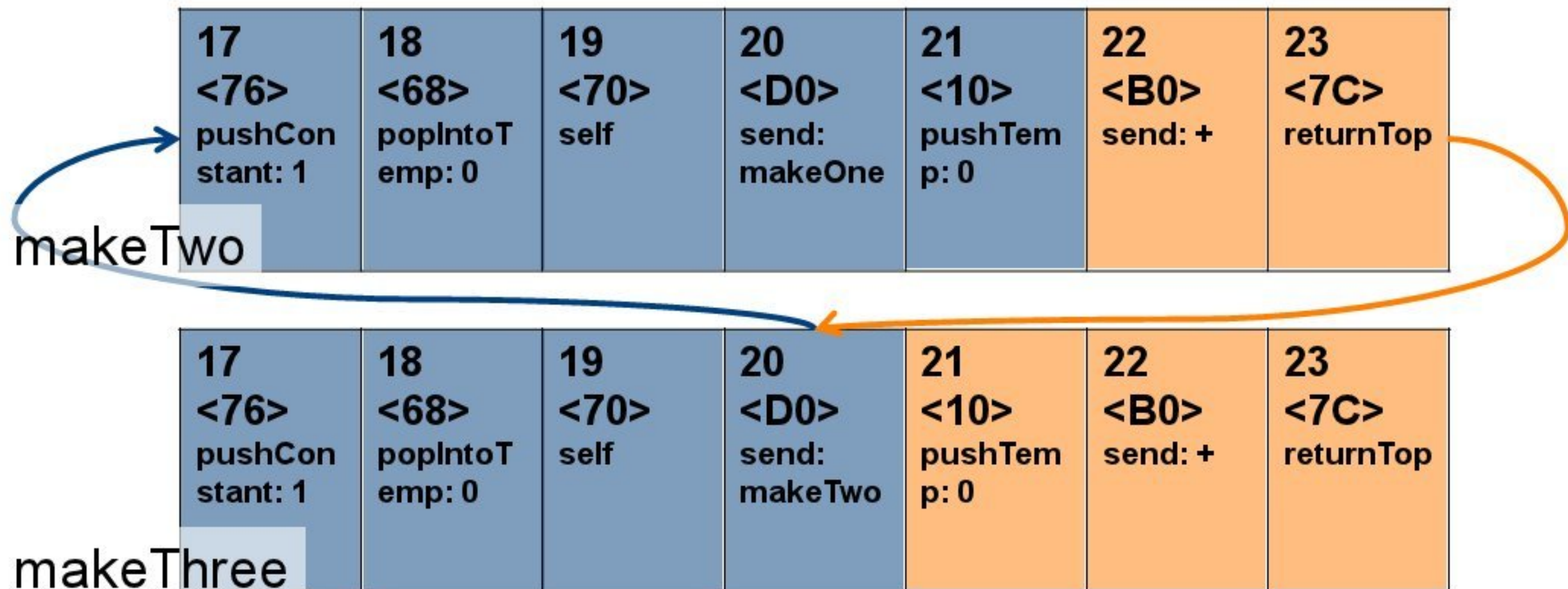
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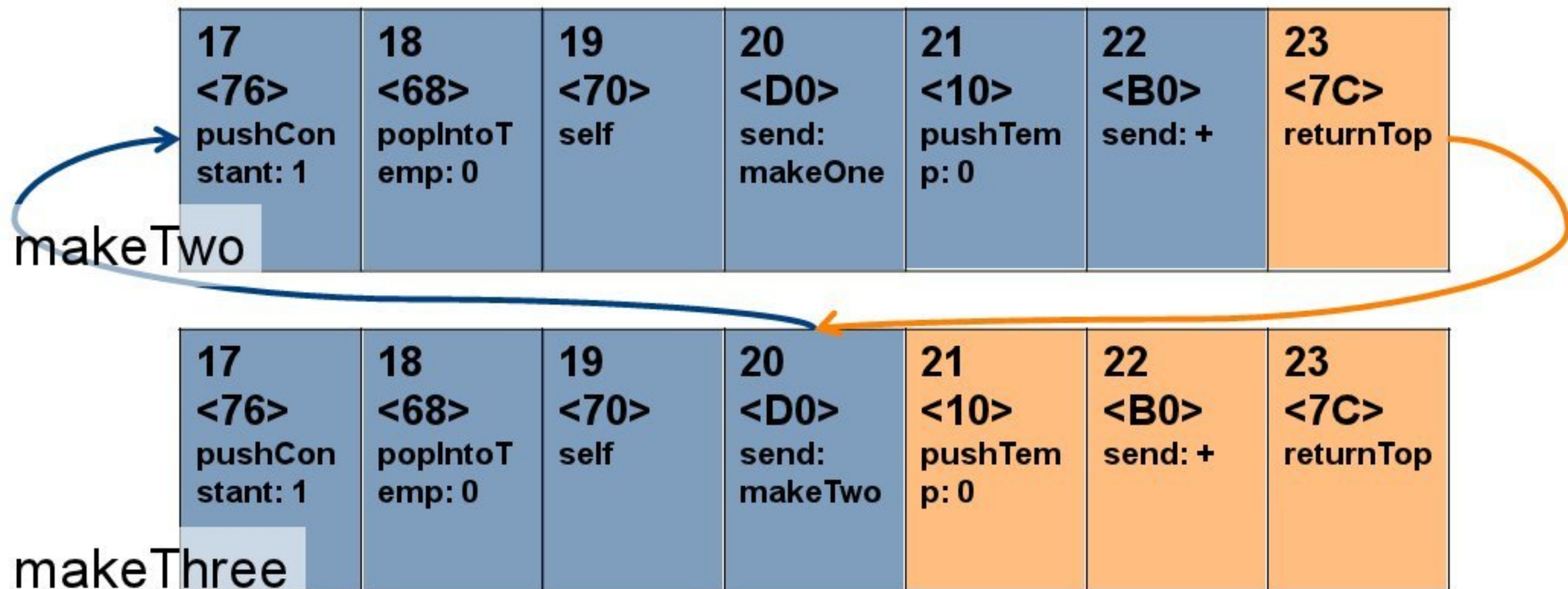
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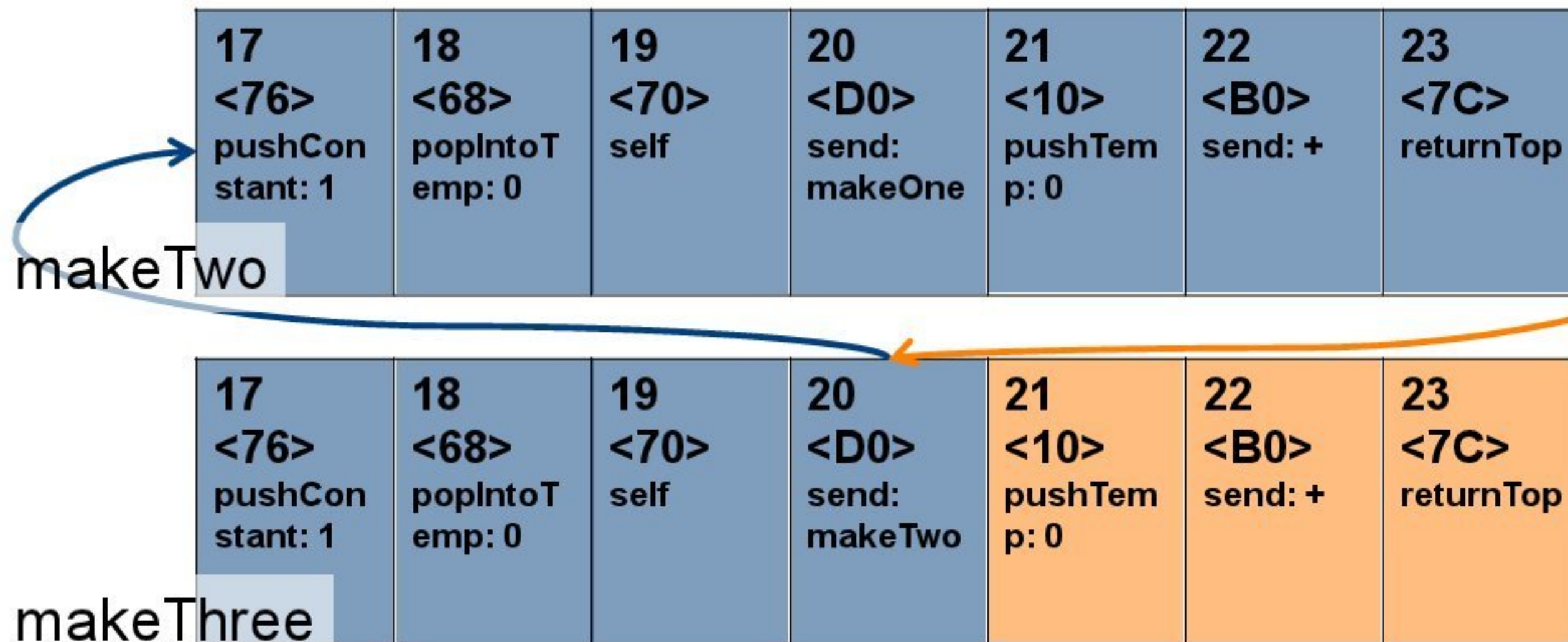
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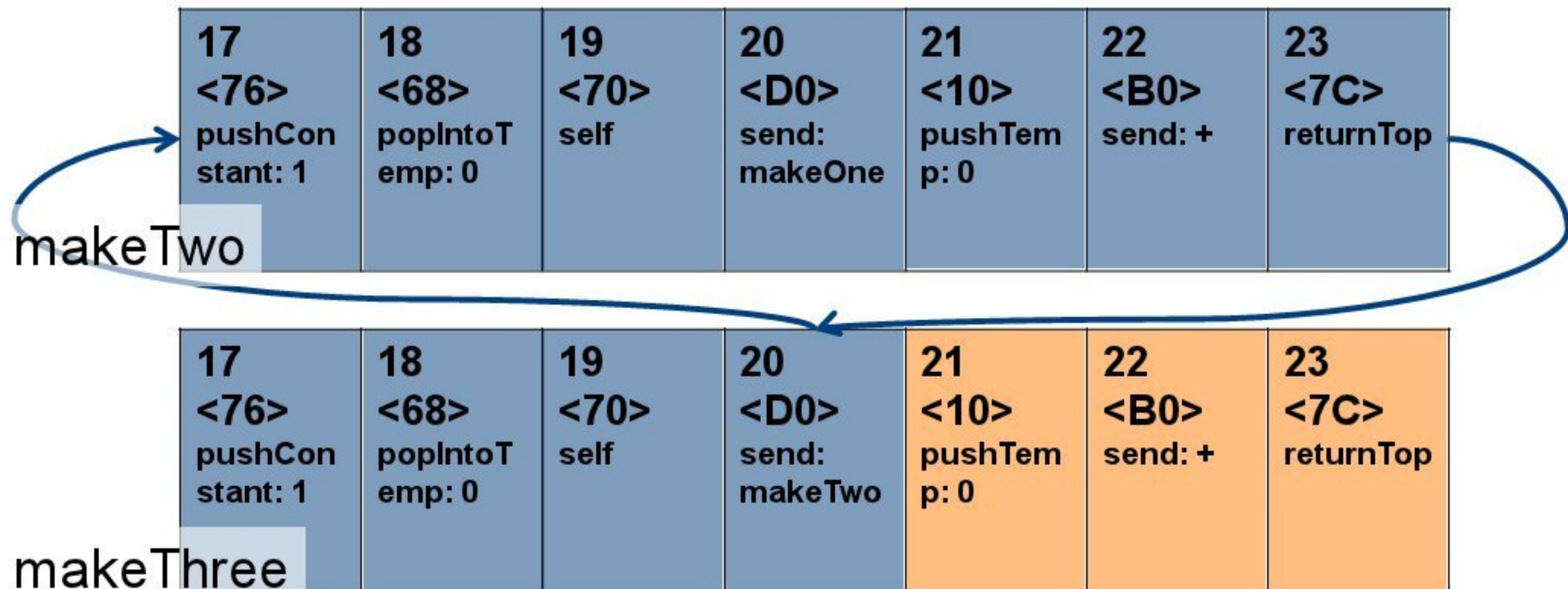
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17 <76> pushCon stant: 1	18 <68> popIntoT emp: 0	19 <70> self	20 <D0> send: makeTwo	21 <10> pushTem p: 0	22 <B0> send: +	23 <7C> returnTop
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makeThree

A Program

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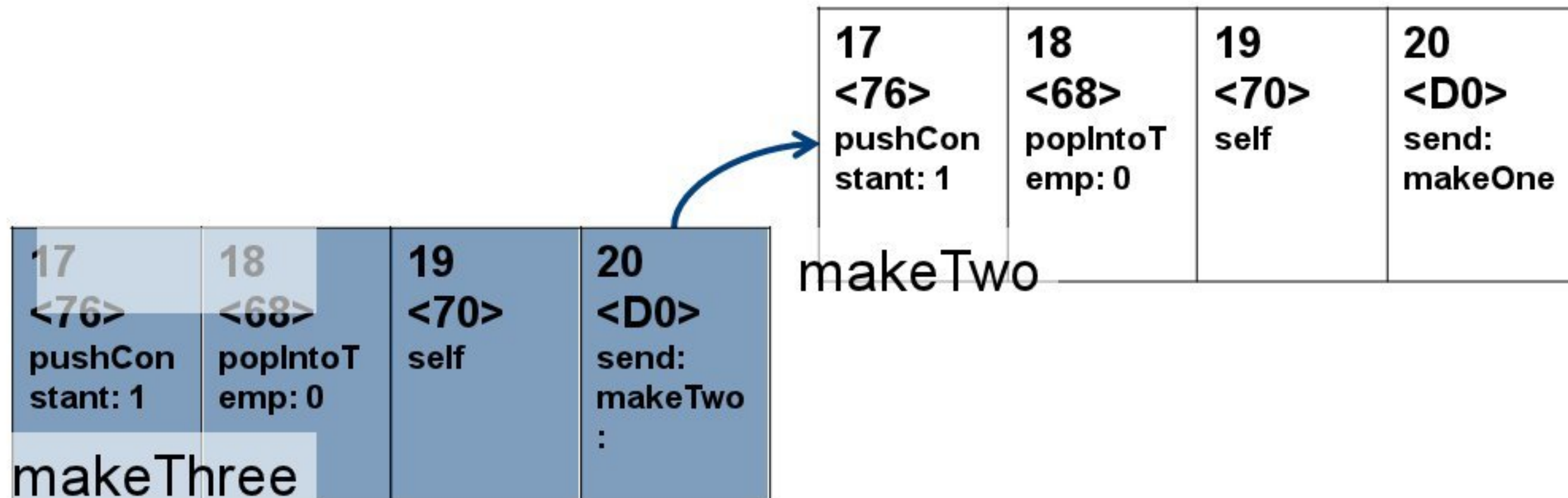
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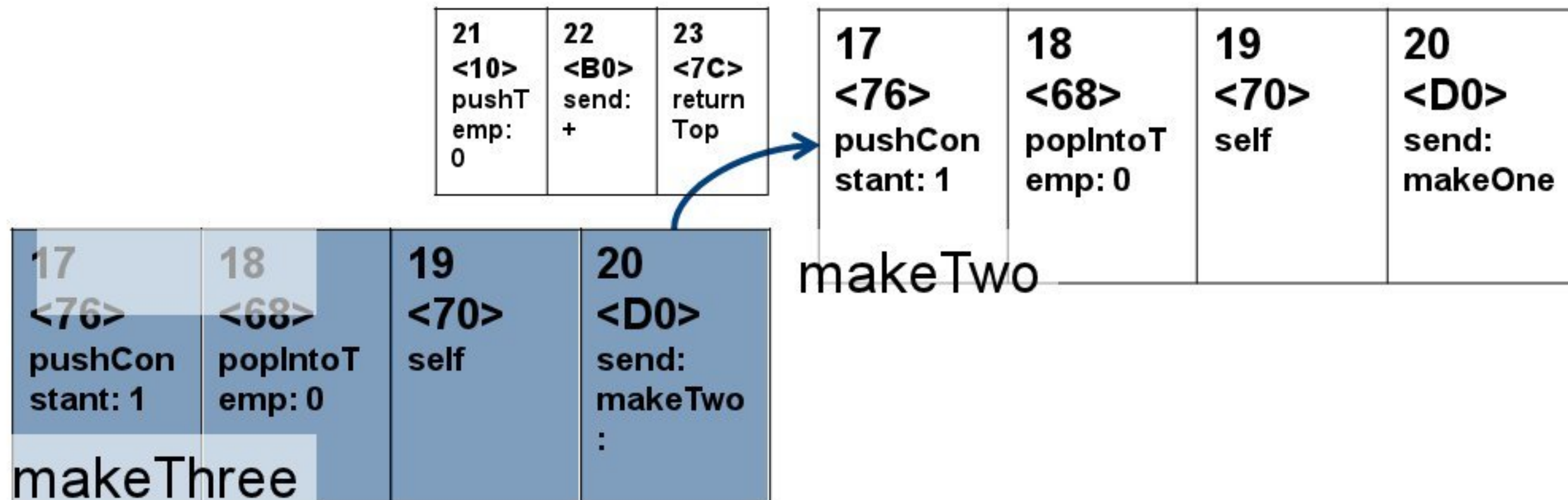
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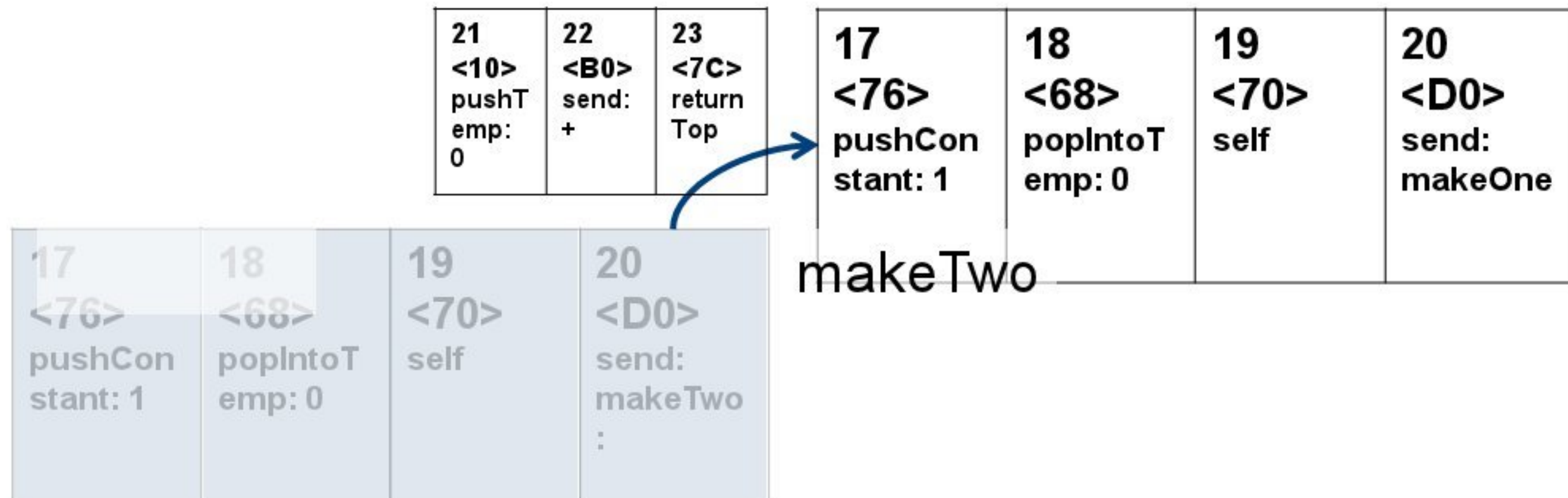
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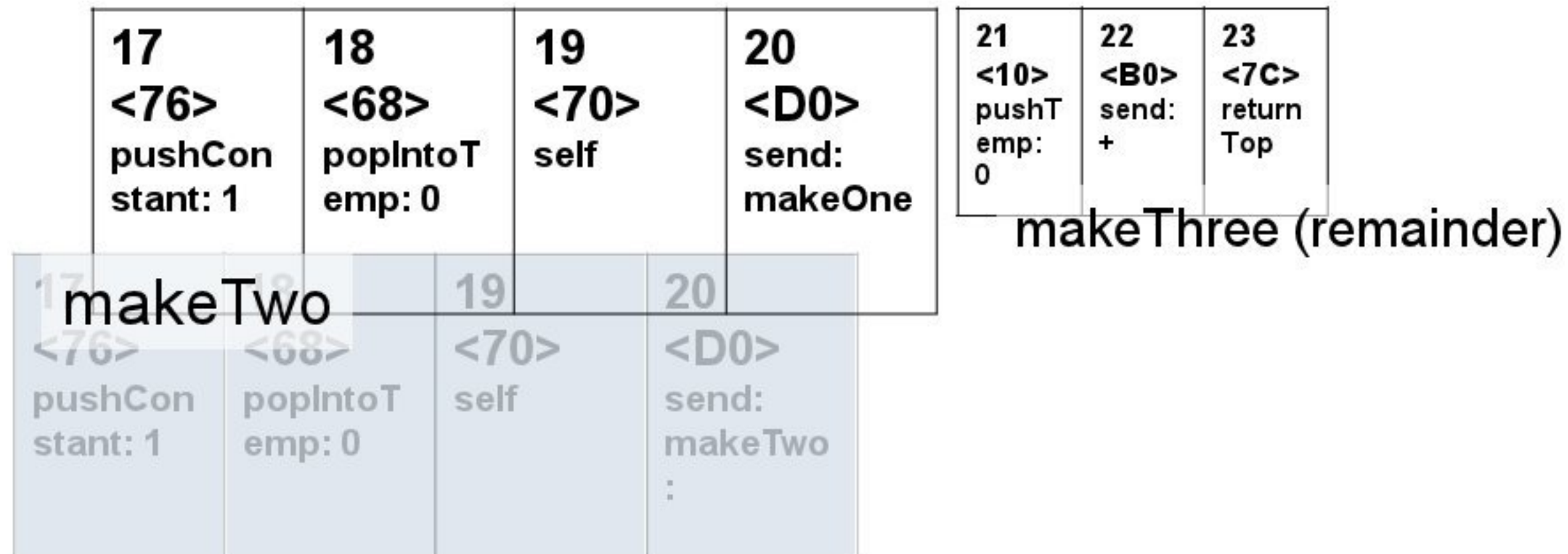
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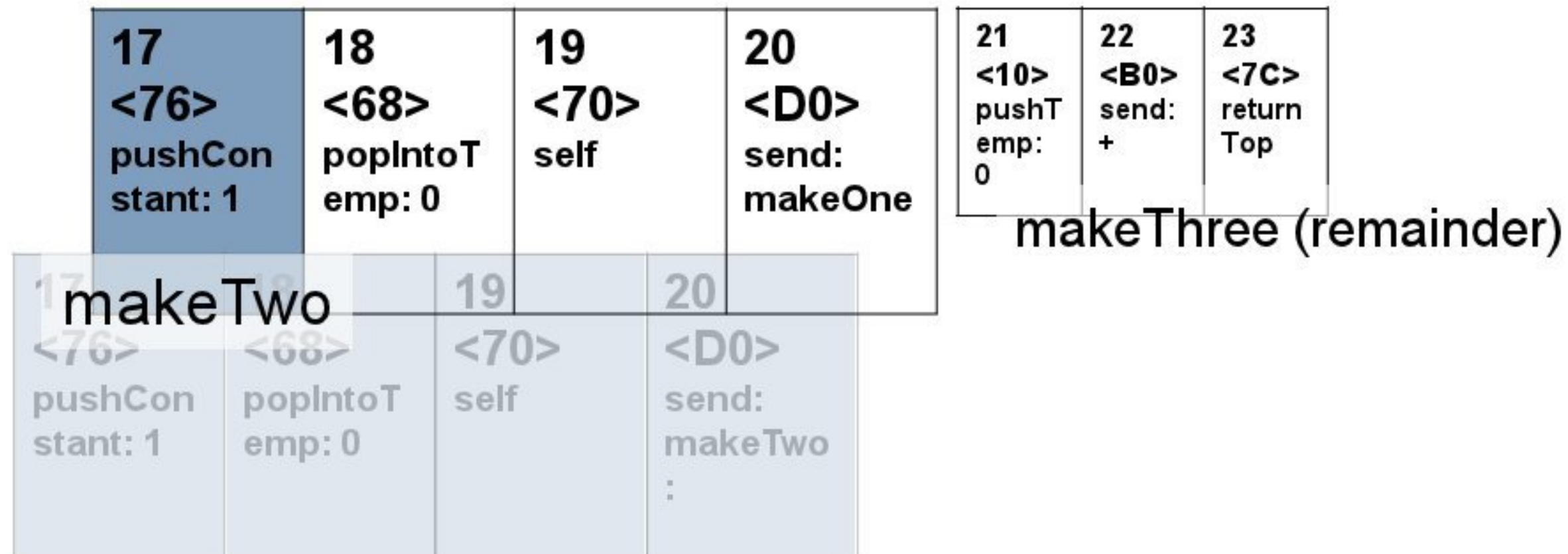
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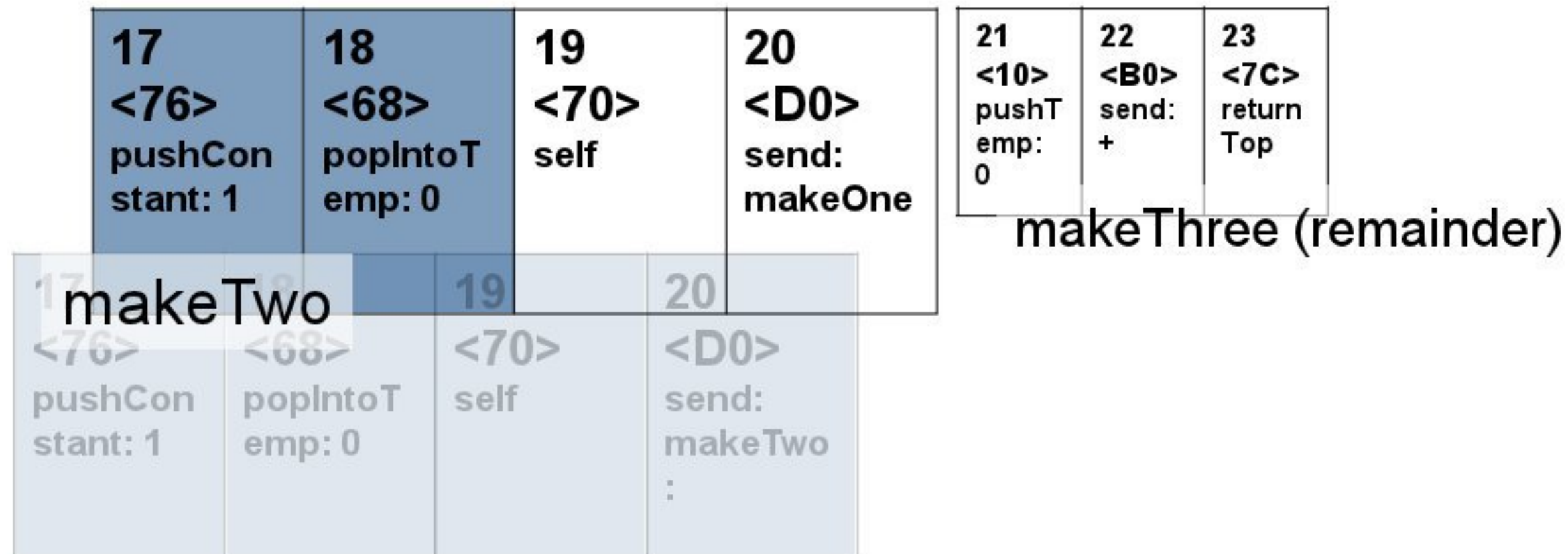
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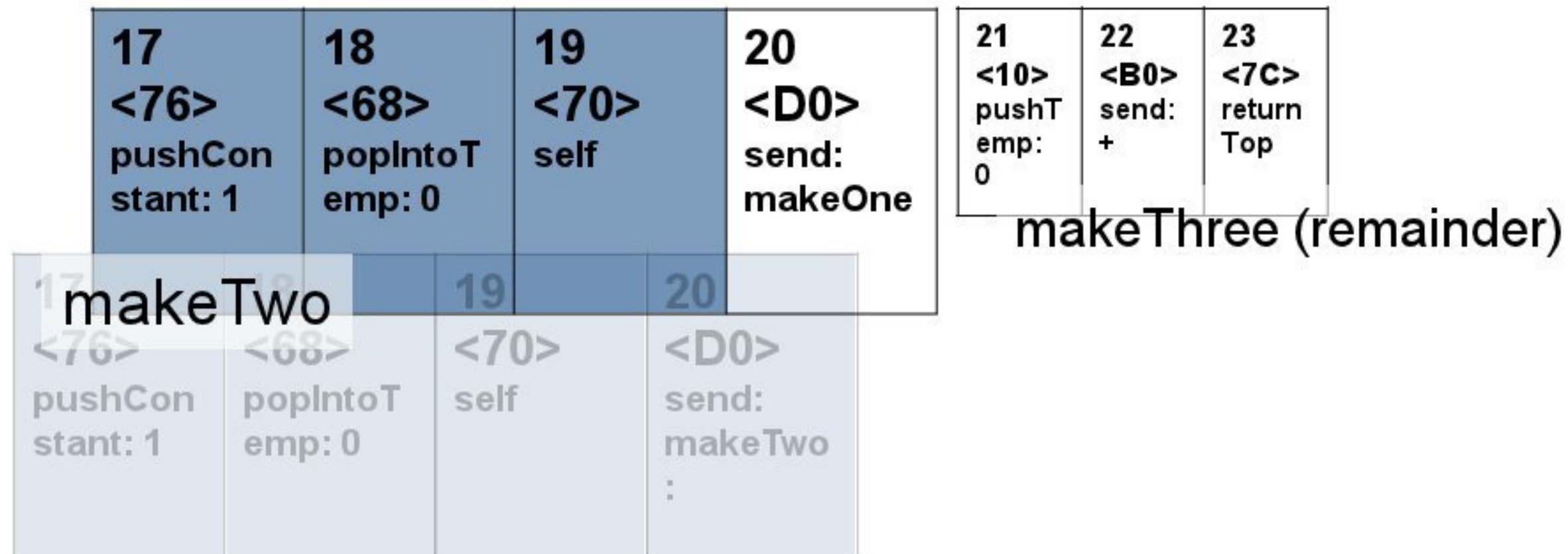
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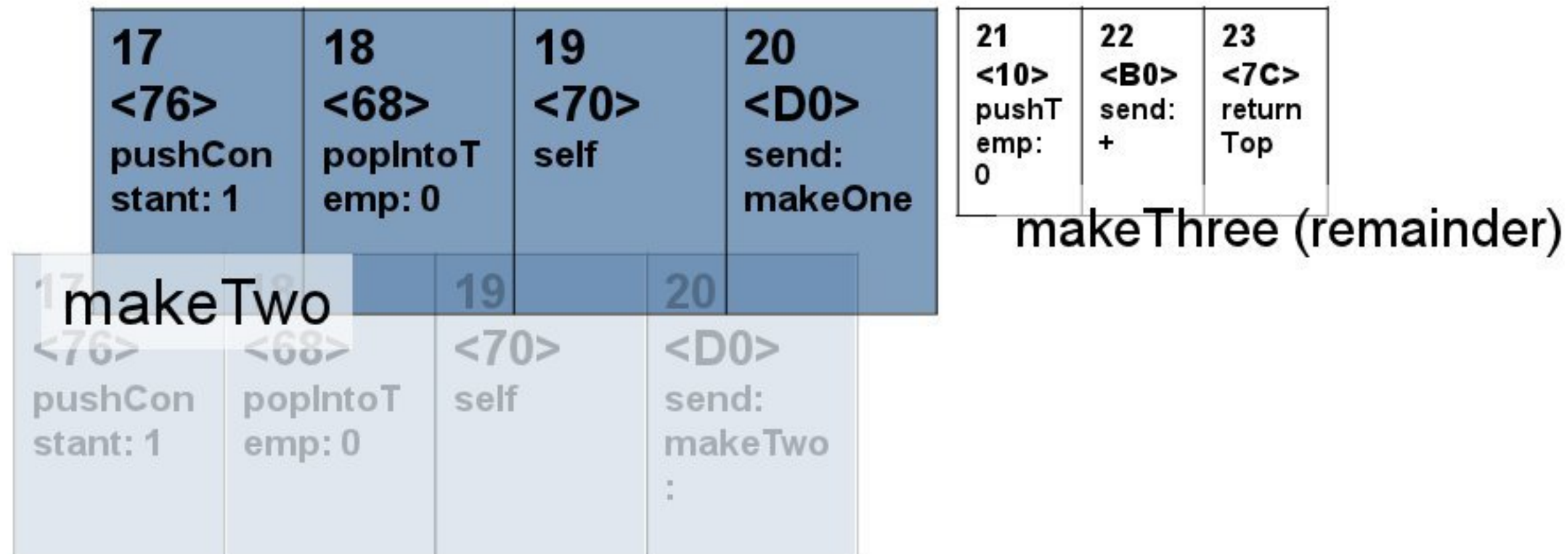
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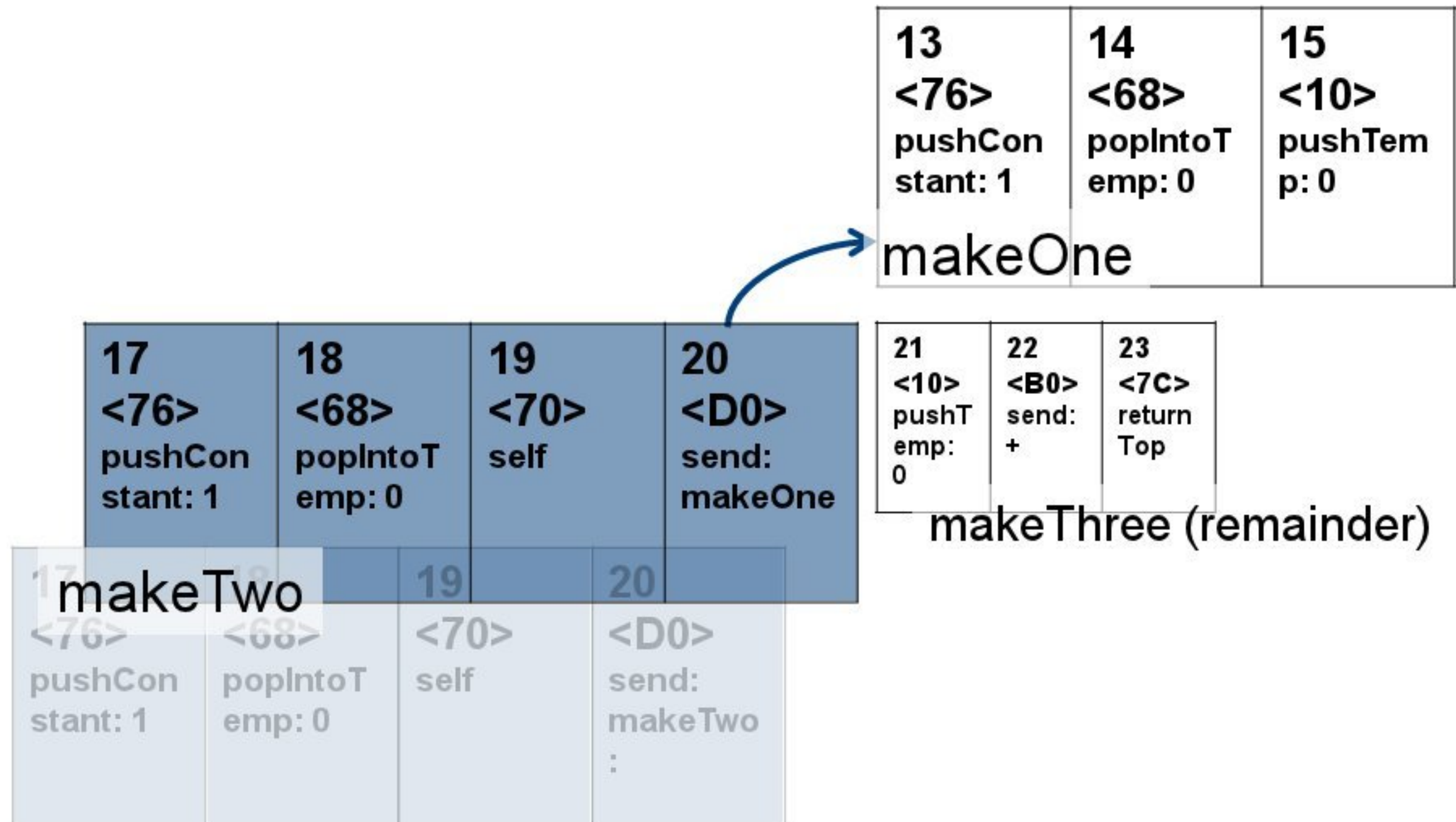
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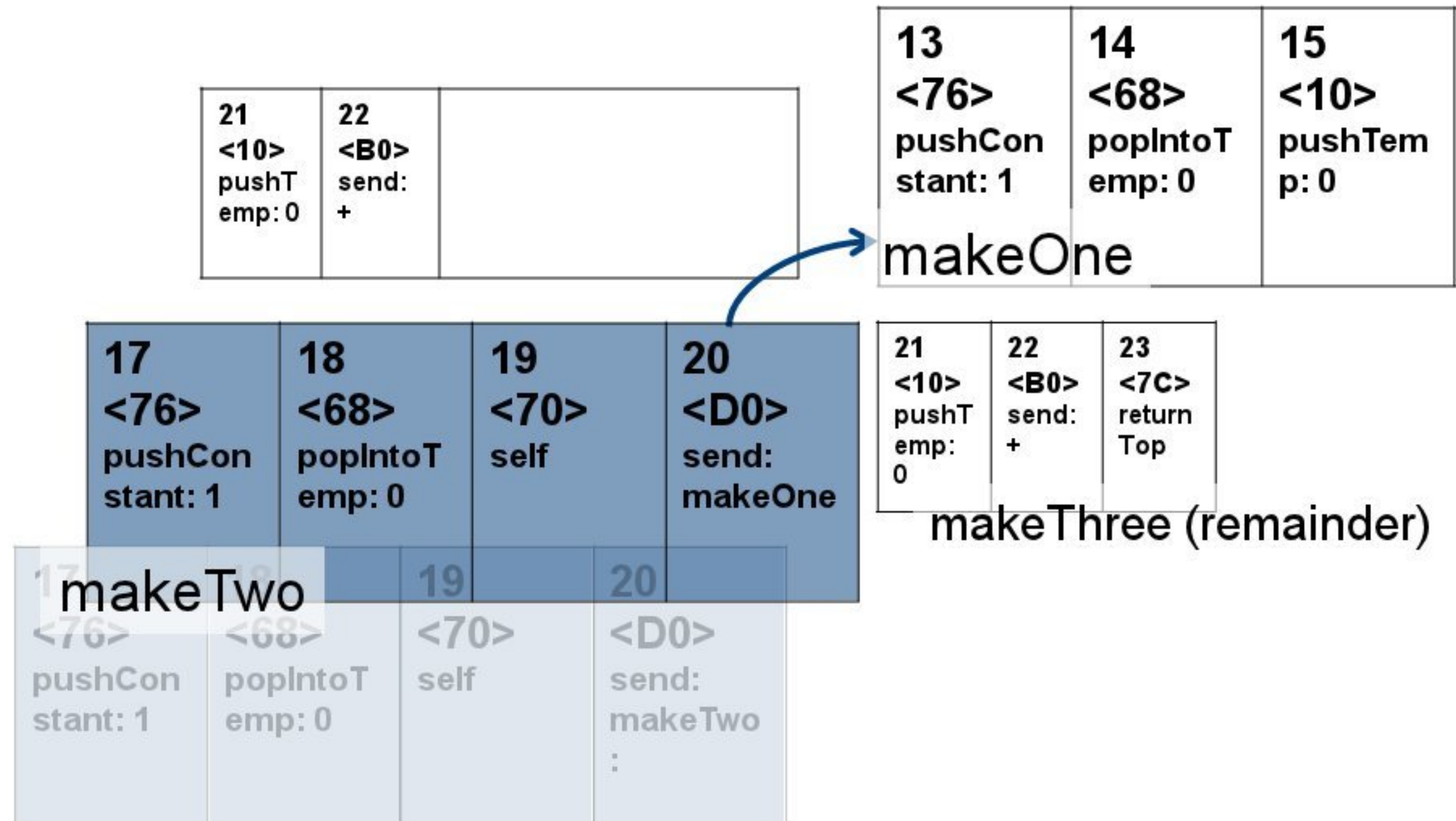
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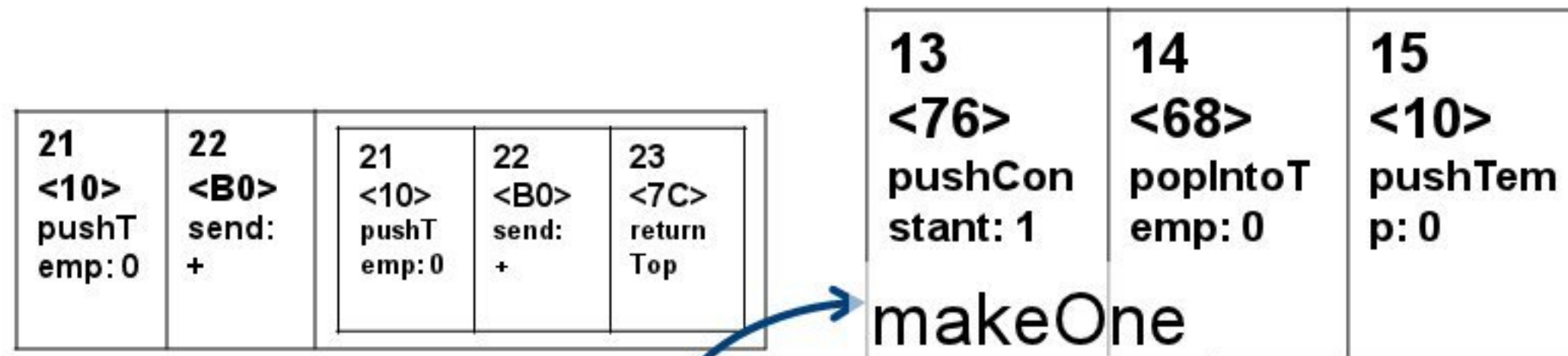
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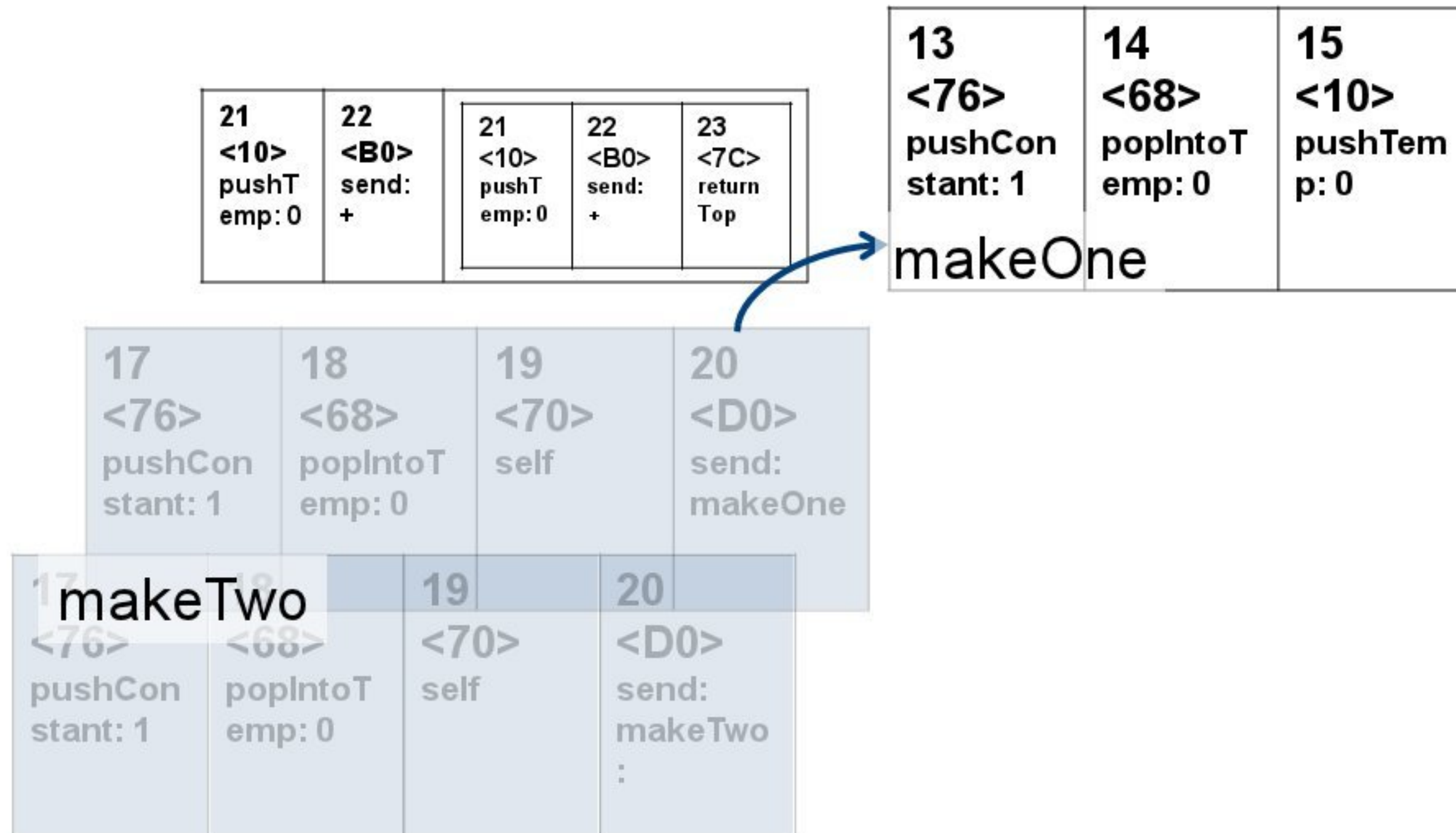
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A Program



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13 <76> pushCon stant: 1	14 <68> popIntoT emp: 0	15 <10> pushTem p: 0
---	--	---

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21 <10> pushT emp: 0	22 <B0> send: +	21 <10> pushT emp: 0	22 <B0> send: +	23 <7C> return Top
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makeTwo + makeThree (remainders)

17 <76> pushCon stant: 1	18 <68> popIntoT emp: 0	19 <70> self	20 <D0> send: makeOne
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makeTwo

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13 <76> pushCon stant: 1	14 <68> popIntoT emp: 0	15 <10> pushTem p: 0
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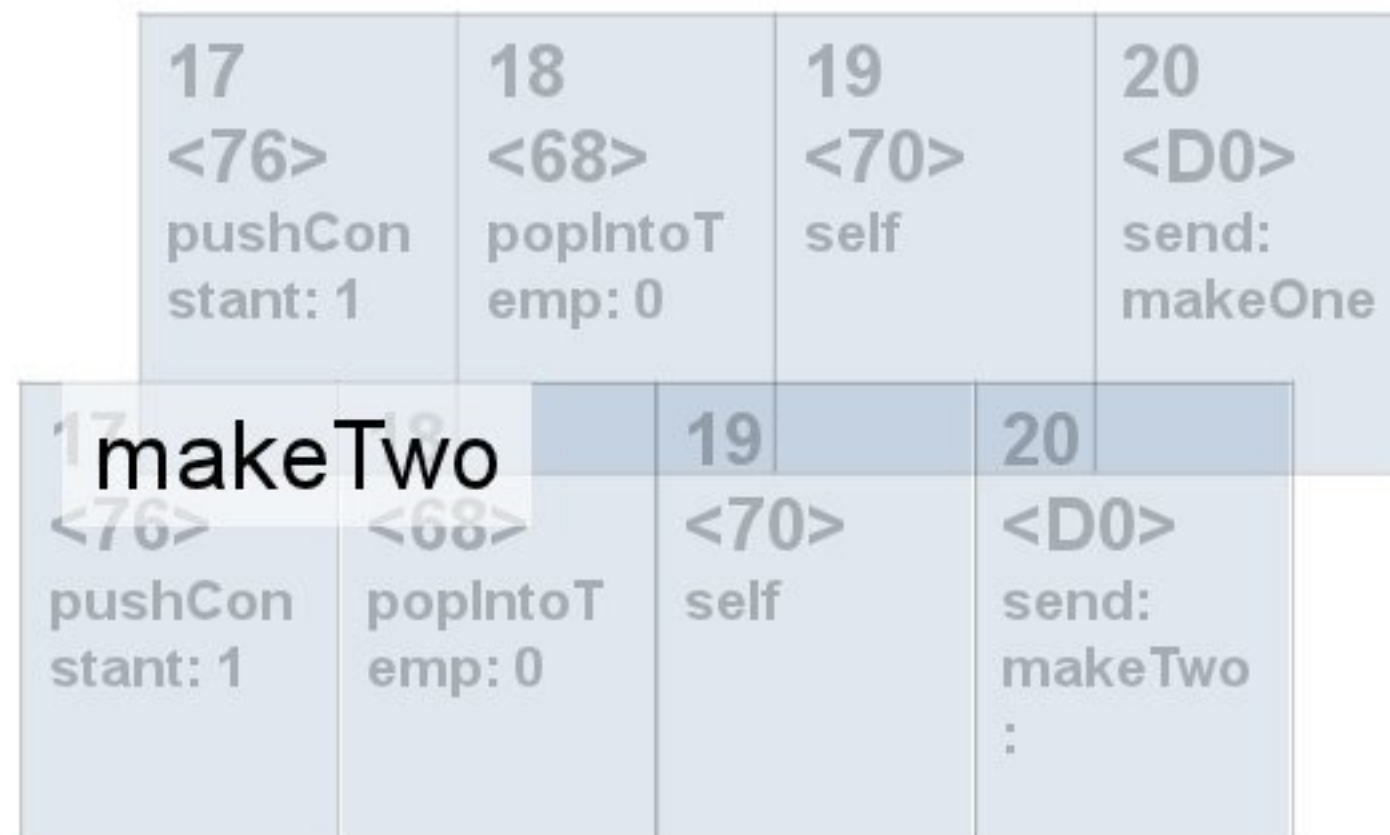
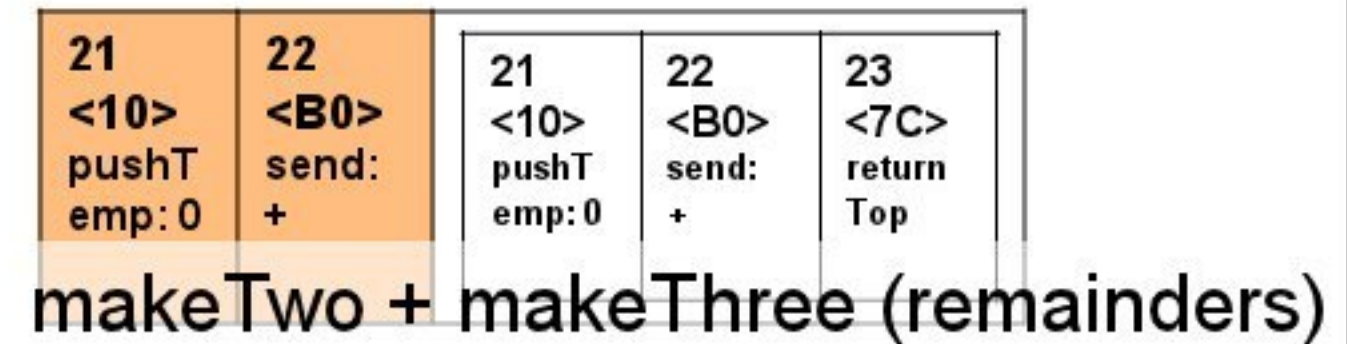
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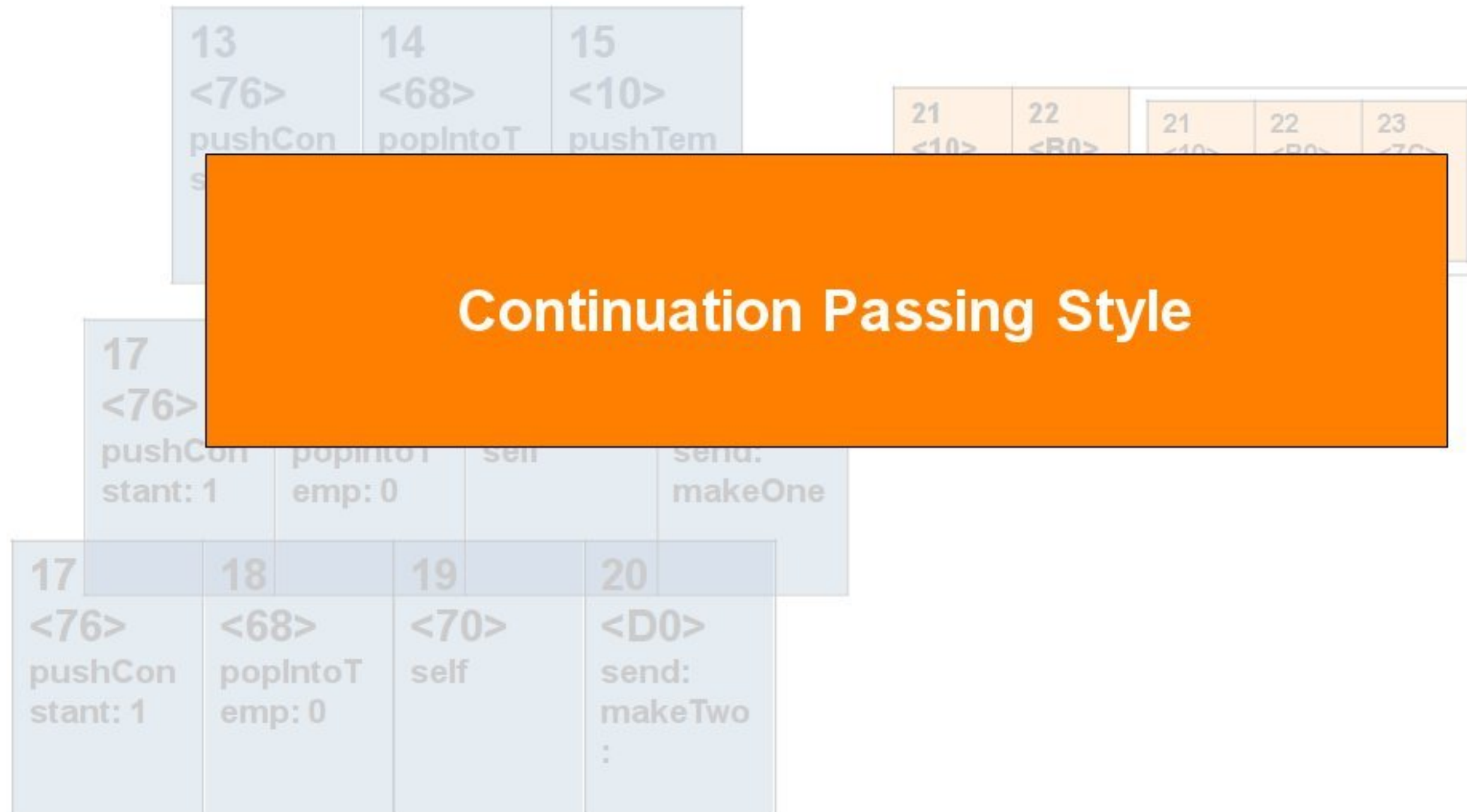
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[:x x + one]	[:y ^ y + one]
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A Closure/Lambda

- an anonymous function
- an object that can be evaluated

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- an anonymous function
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```
| name |  
name := 'Tim'.  
[:greeting | ^ greeting, ' ', name] value
```

A Closure/Lambda

- an anonymous function
- an object that can be evaluated

```
| name |  
name := 'Tim'.  
[:greeting | ^ greeting, ' ', name] value
```

- 1 argument
 - greeting
- code
 - greeting , ' ' , name
- context
 - {#name -> 'Tim'}

A Program

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[:x x + one]	[:y ^ y + one]
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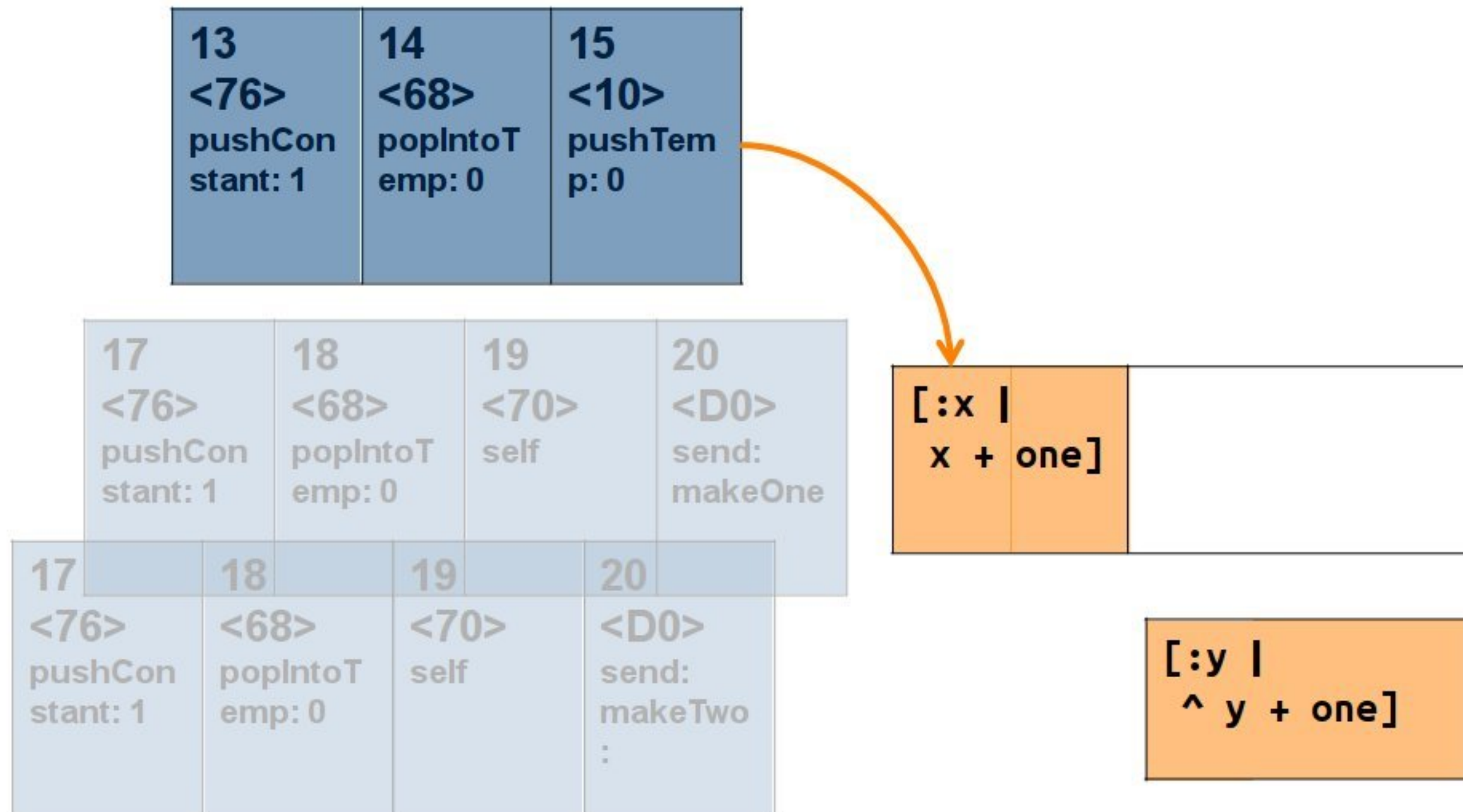
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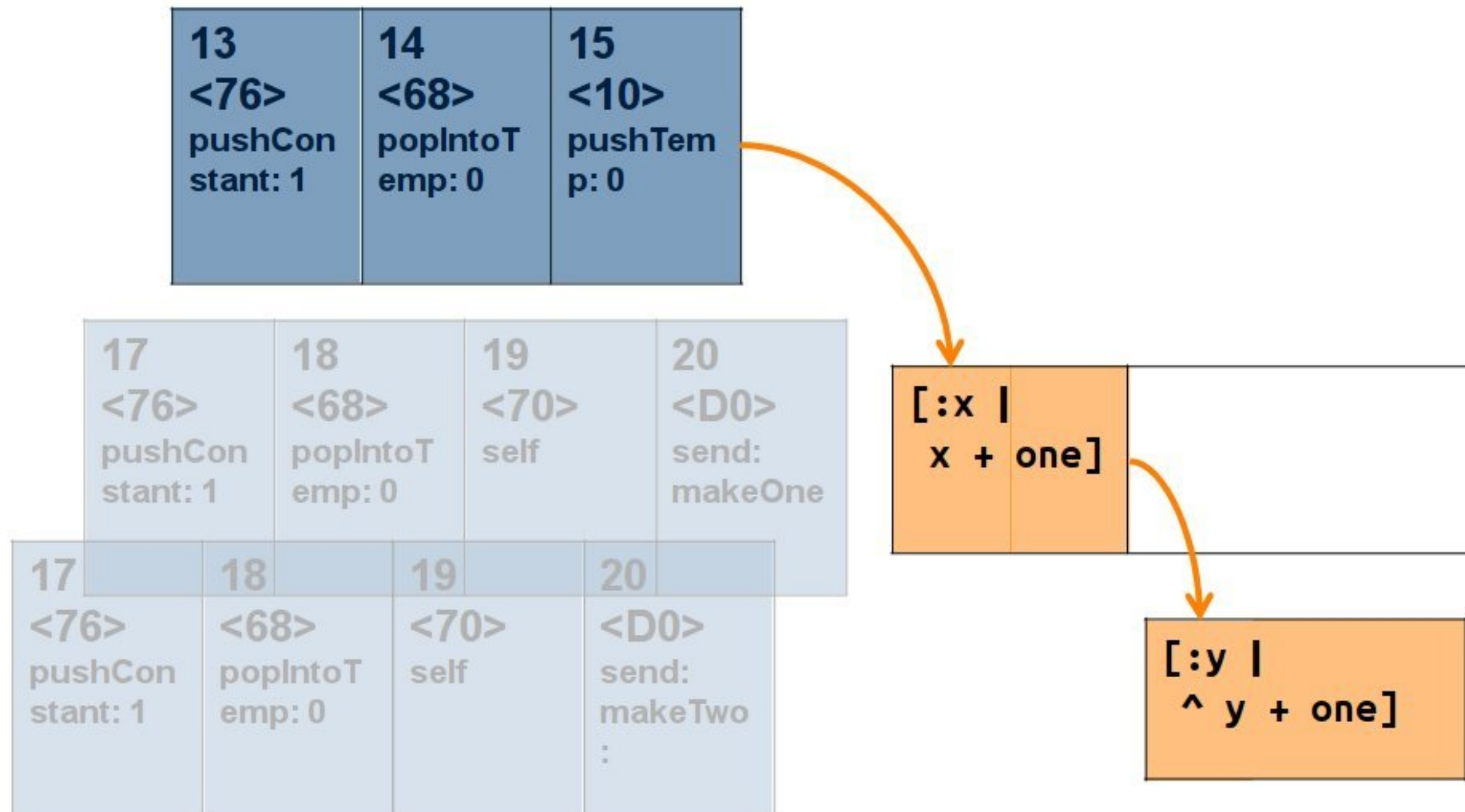
[:x x + one]	
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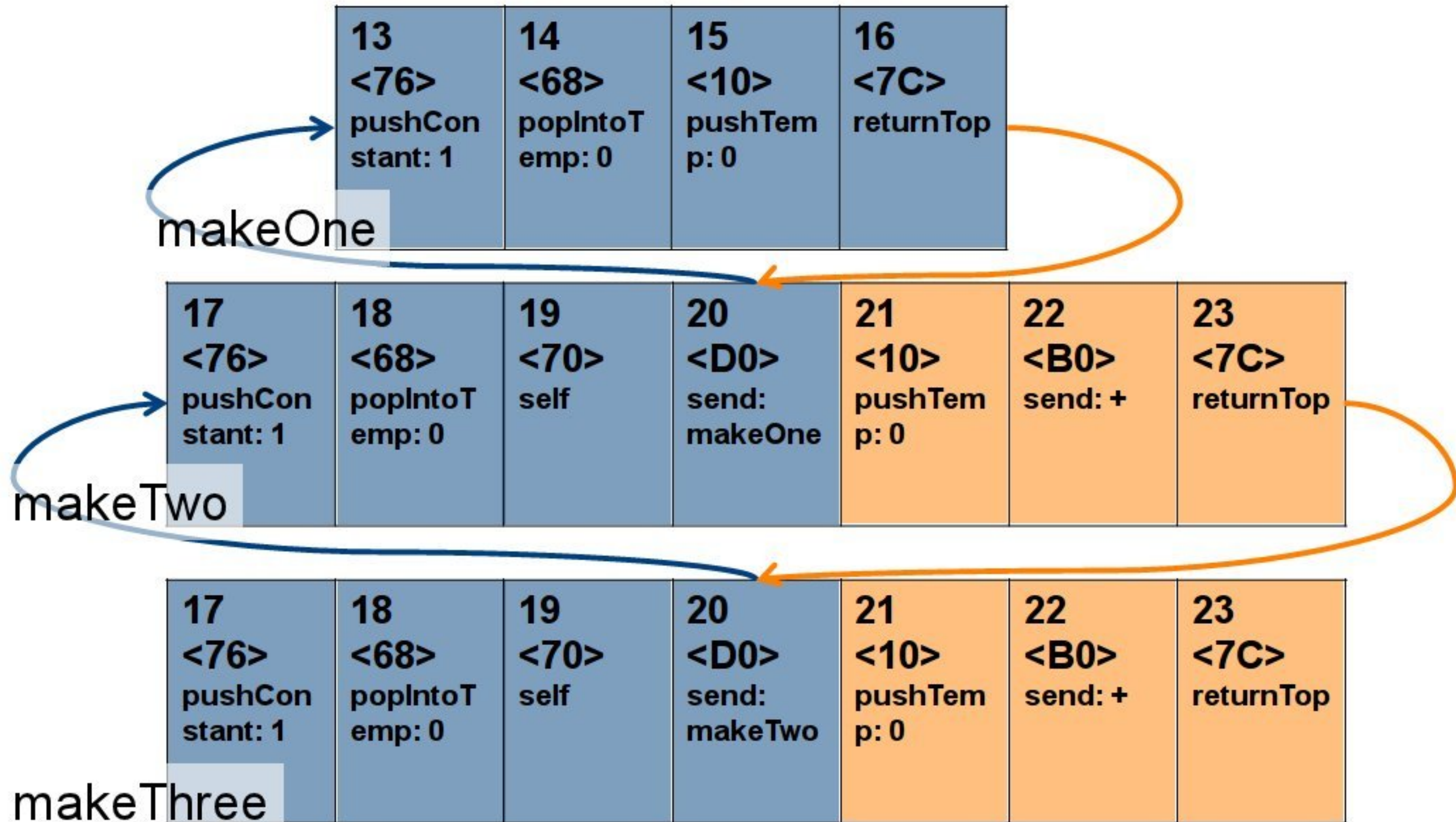
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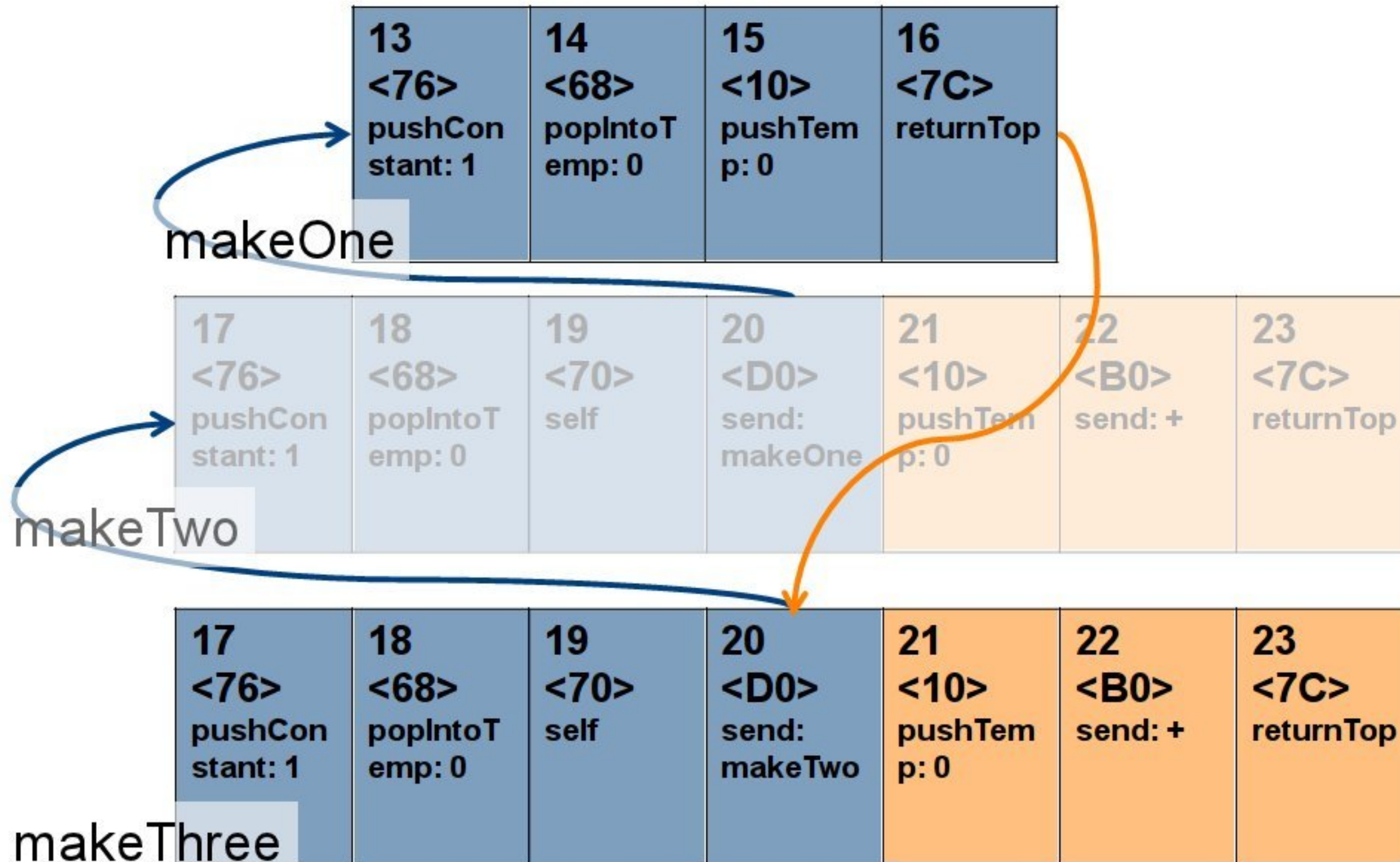
A Program



A Program



A Program



A Continuation

- reification of the execution state in form similar to a closure
 - expects one argument
 - points to a code offset
 - carries the creation context
- contrary to a closure, a continuation returns from the **original creation site**, not to the **caller**
- simple form: exceptions, `setjmp/longjmp`
 - only from lower stack levels

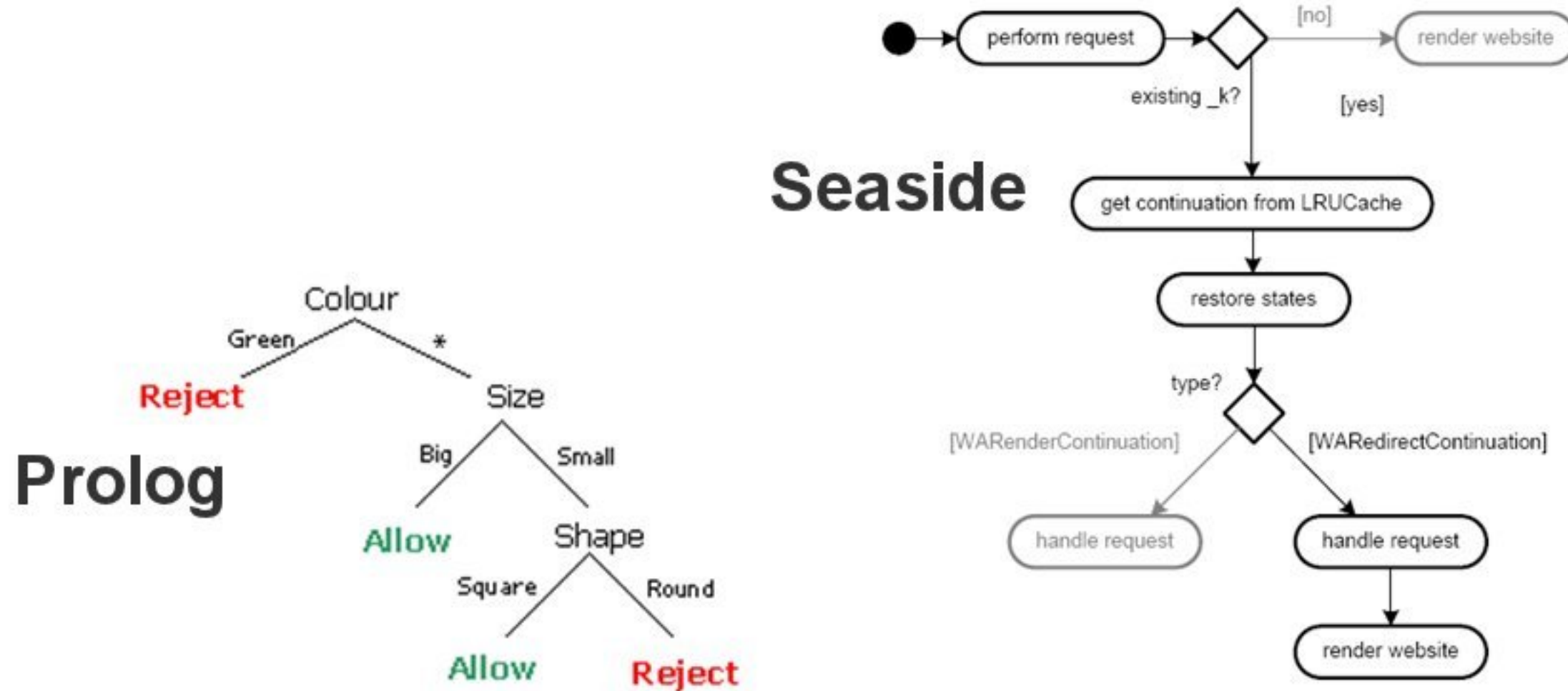
GOTO, Exceptions, Tail-recursion, Backtracking

DEMOS

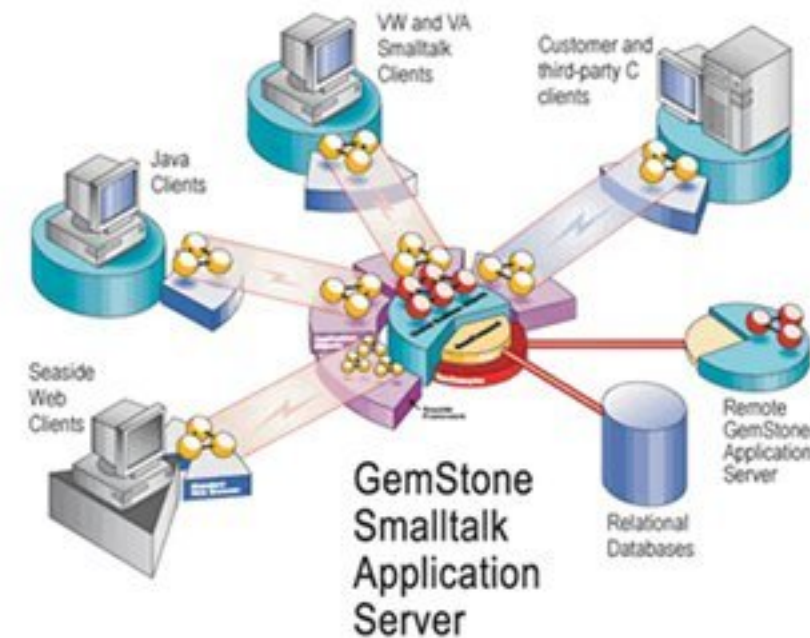
Applications

- co-routines
 - co-operative multi-tasking
 - generators
 - iterators
 - worker queues
 - parsers
 - compilers
 - state-machines
-

Higher-level Applications

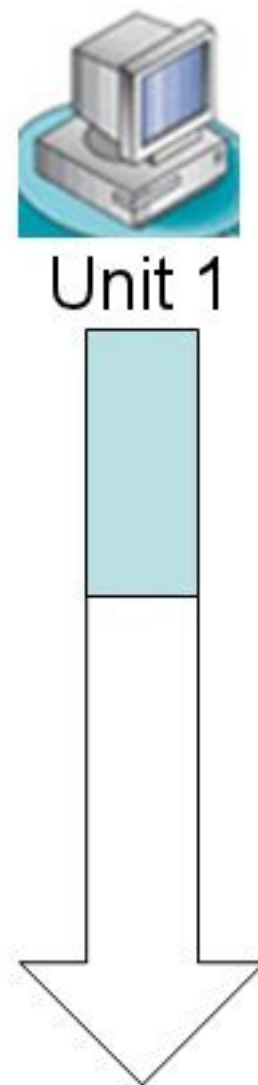


Distributed Computing



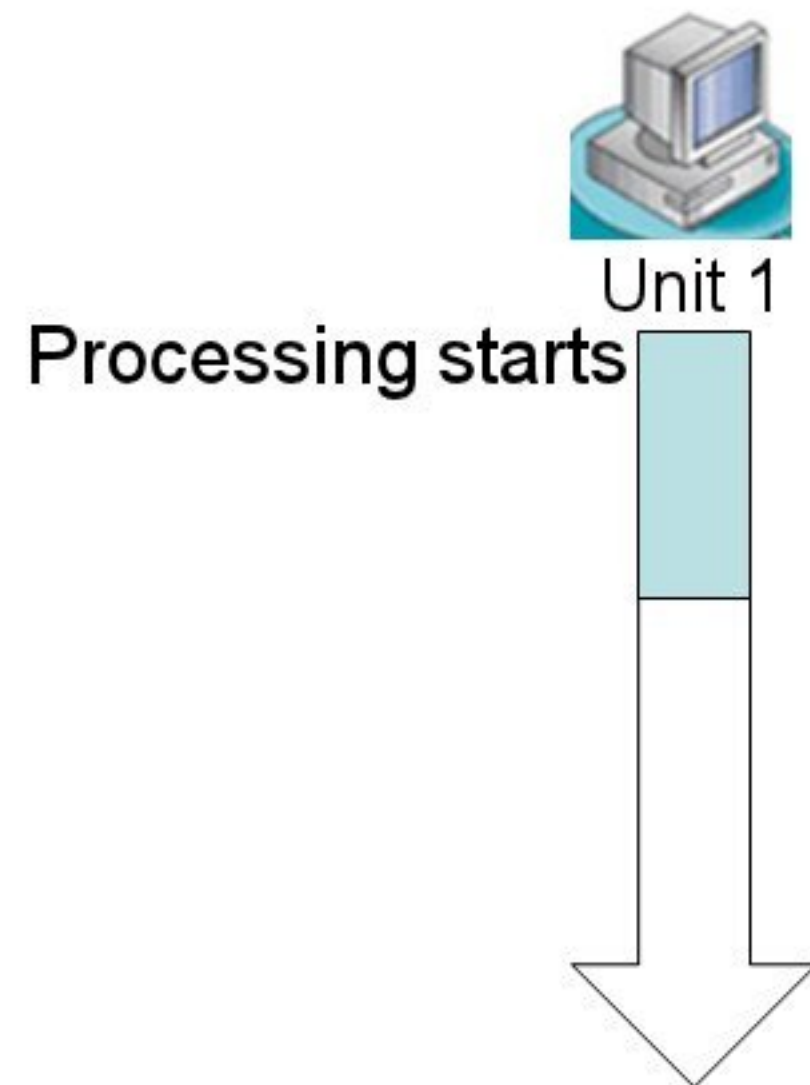
Distributed Computing

- Distributed processing
- Central work queue



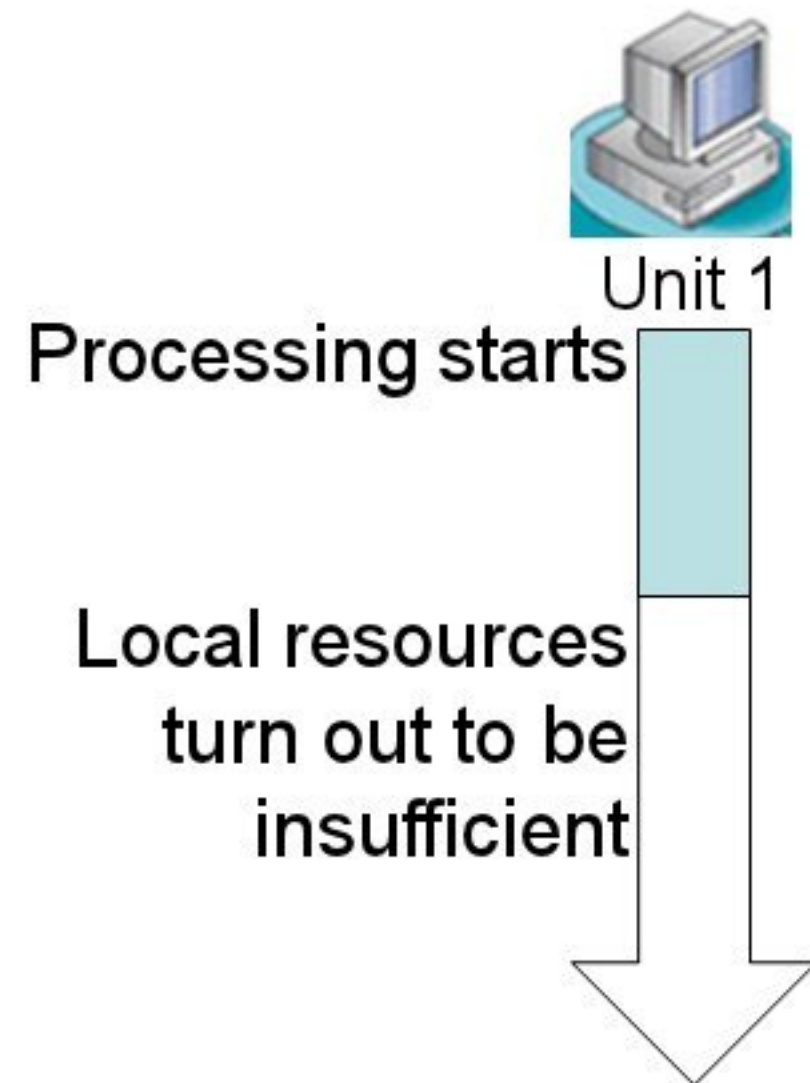
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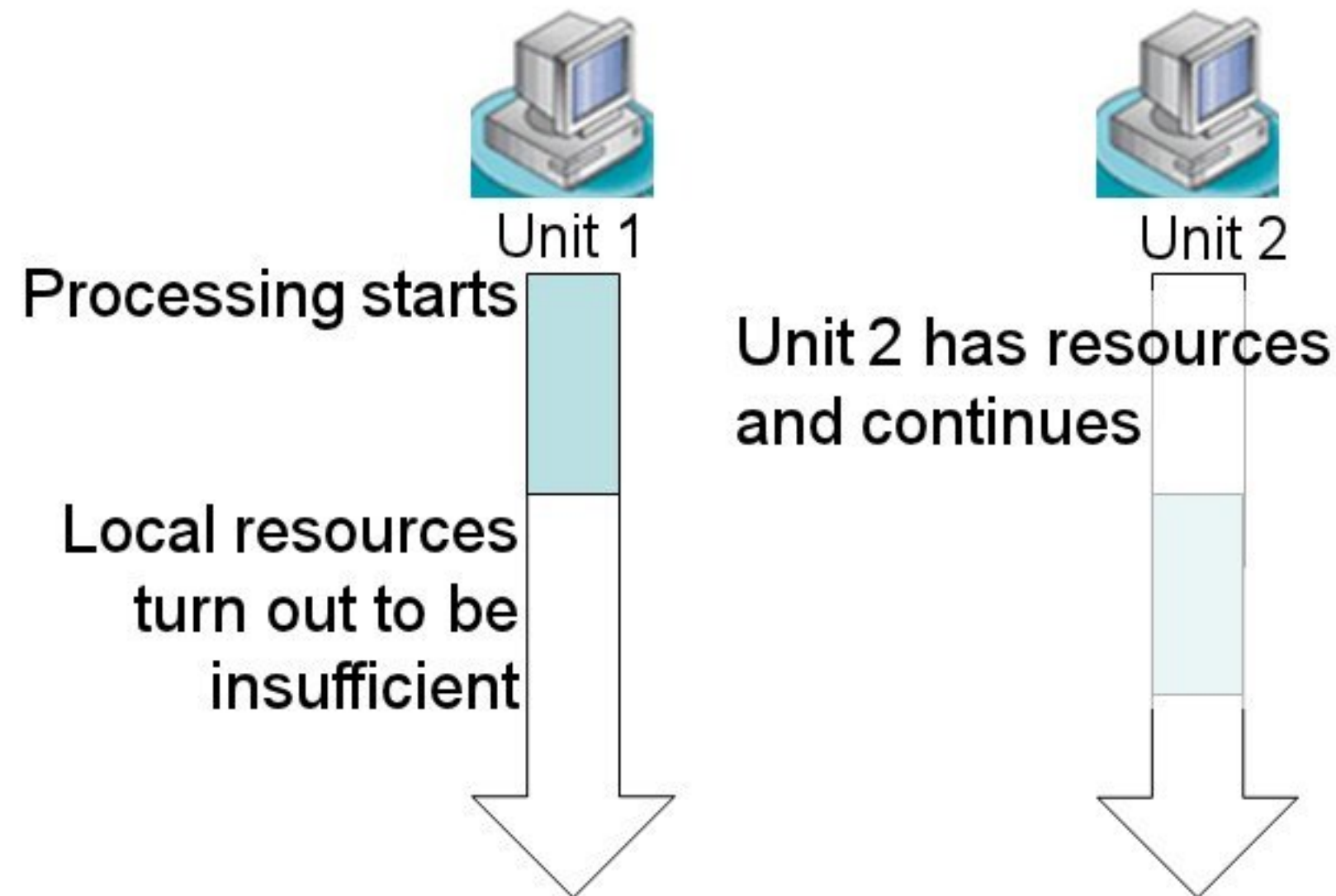
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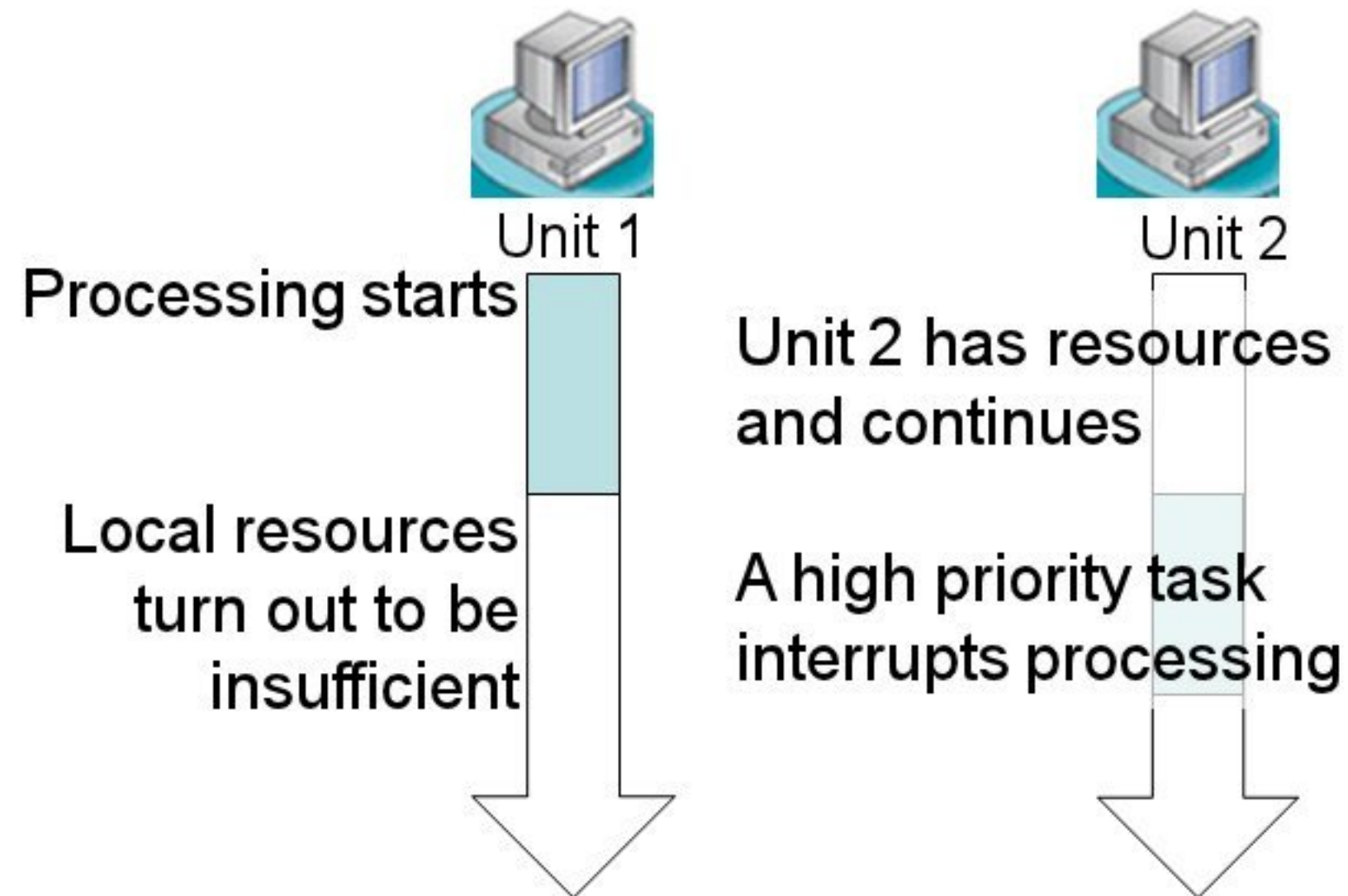
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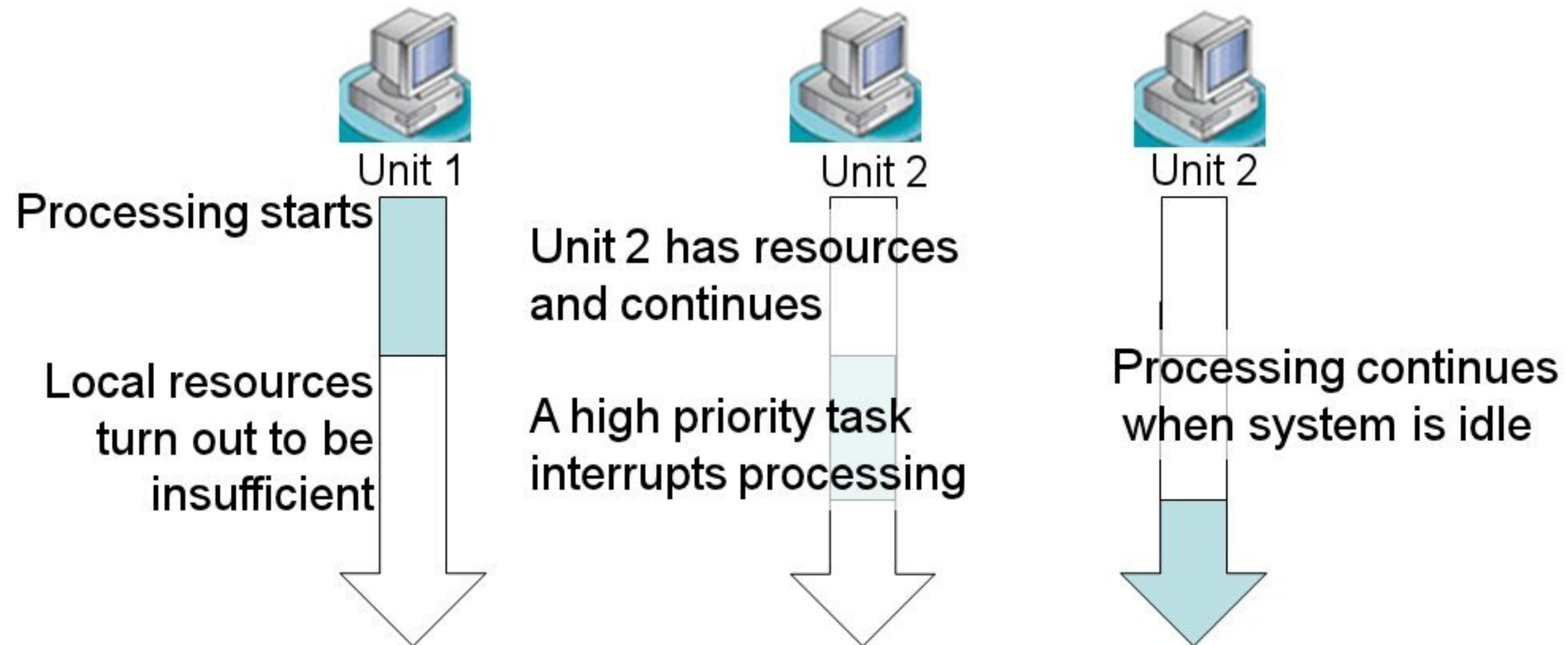
Distributed Computing

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Distributed Computing

- Distributed processing
- Central work queue



Conclusions

- Continuations are more powerful than closures or exceptions alone
- GOTO is still considered harmful
- With great power comes great responsibility

References

- Implementation Strategies for First-Class Continuations, W.D. Clinger, A.H. Hartheimer, E.M. Ost
- A Library of High Level Control Operators, C. Queinnec
- Implementing First-Class Polymorphic Delimited Continuations by a Type-Directed Selective CPS-Transform, T. Rompf, I. Maier, M. Odersky
- Shift to control, Chung-chieh Shan
- Scheme R5 Proceedings